

## 7

## Metallurgy

## SYLLABUS

- (i) Definition of Metals and Non-metals.  
*Self-explanatory.*
- (ii) Position of the metals (Alkali metals and alkaline earth metals) in the Periodic Table and general characteristics applied to these elements with reference to the following — occurrence, nature, bonding, action of air, action of water, action of acids.  
*Self-explanatory.*
- (iii) Comparison of Metals and Non-metals.  
*General properties with special reference to physical properties: state, lustre, melting point, density, ductility, malleability, brittleness, conduction of electricity (exceptions to be specifically noted – e.g. graphite, mercury); chemical properties: a metal forms at least one basic oxide; non-metal, an acidic or neutral oxide; discharge of metallic ions at the cathode from fused metallic chlorides (link with bonding and ion formation); many metals liberate hydrogen from dilute HCl and H<sub>2</sub>SO<sub>4</sub>.*  
*In the physical properties of metals and non-metals, atomicity and valence electrons should also be included; suitable examples must be given for basic, acidic and neutral oxides; formation and discharge of ions at the cathode (metallic) and anode (non-metallic) should be explained with examples.*
- (iv) Reduction of metallic oxides; some can be reduced by hydrogen, carbon and carbon monoxide (e.g. copper oxide, lead oxide, iron (II) oxide) and some cannot (e.g. Al<sub>2</sub>O<sub>3</sub>, MgO - refer to activity series).  
*Equations with conditions and observations should be given.*
- (v) Extraction of metals based on the activity series.  
*Extraction of metals: Principle of extraction of metal from its compounds by reduction – carbon reduction, electrolytic reduction. Active metals by electrolysis e.g. sodium, aluminium (reference only).*
- (iv) Corrosion of iron and its prevention  
*Experiment to illustrate that moisture and oxygen in air are responsible for the corrosion : Reaction of corrosion, Prevention by painting and galvanization.*
- (vii) Metals and their alloys : common ores of iron, aluminium and zinc. Extraction of Aluminium;  
*Metals and their alloys : Occurrence of metals in nature - mineral and ore. Common ores of iron, aluminium and zinc. Dressing of the ore - hydrolytic method, magnetic separation, froth floatation method, chemical method by using chemical - NaOH for purifying bauxite – Baeyer's process.*  
*Extraction of Aluminium : the constituents in the charge, method of electrolytic extraction (flow chart to be used); structure of electrolytic cell and reason for using cryolite, electrolyte, electrodes, electrode reaction.*  
*Description of the changes occurring, purpose of the substances used and the main reactions with their equations.*
- (a) *Uses of iron, aluminium and zinc and their alloys.*  
*Uses of iron, aluminium and zinc and their alloys. Composition of their alloys – steel, duralumin, brass.*
- (b) *Other important alloys — bronze, fuse metal and solder*  
*Uses only*

## 7A. METALS AND NON-METALS

## 7.1 INTRODUCTION

There are 118 different elements known to us today. These elements are widely distributed in earth's crust in free state as well as in the combined form.

Approximate relative abundance of some elements in the earth crust are :

Oxygen	46.6%	Silicon	27.7%
Aluminium	8%	Iron	5%
Calcium	3.6%	Sodium	2.8%
Potassium	2.8%	Magnesium	2.1%
Hydrogen	0.14%	Phosphorus	0.12%



These elements have been classified into **metals** and **non-metals** based on their properties. Of these known elements, only 22 are non-metals.

All the metallic elements (except mercury) are solids whereas 11 non-metals are gases, one is a liquid (bromine) and the remaining non-metals are solids.

## 7.2 METALS

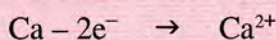
The knowledge of metals is very old. *Copper was the first metal to be used by man* for making utensils, weapons and for other purposes.

Gold, silver, copper, lead, iron, tin, antimony and mercury (earlier named **quick silver**) have been known to mankind from the ancient times.

Metals are widely used in our daily life for a large number of purposes. Some of the metals are used in making *jewellery and coins*; some are employed in making utensils and furniture, and some in the construction of heavy machinery, tools, transport vehicles and many in the manufacturing of other equipments. Metals often find applications as *catalysts* in various industrial processes such as hydrogenation of vegetable oils, manufacture of ammonia, sulphuric acid, nitric acid, dyes, drugs, etc. Metals, though in small quantities, have also been recognized as essentials for various biological processes. *For example, iron is a constituent of blood pigment and magnesium of plant pigment.*

Metals are defined as the *elements which form positive ions by the loss of electrons.*

**For example:** Sodium, magnesium and aluminium are metals because they form positive ions by the loss of 1, 2 and 3 electrons respectively.



**Note :** Hydrogen is a **non metal**, which forms positive ion.



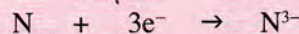
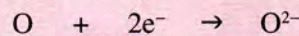
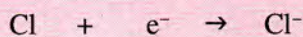
## 7.3 NON-METALS

Non-metals though small in numbers play a very vital role in our daily life.

Hydrogen, the lightest element known, is used in the hydrogenation of vegetable oils to make ghee, as a fuel and in the manufacture of compounds. It is also the essential part of organic compounds. Proteins, fats, carbohydrates, enzymes, vitamins, etc., are all compounds of carbon, and are essential for the growth and development of living organisms. The presence of oxygen gas in air is essential for respiration, and for combustion. Nitrogen is the most abundant element present in the atmosphere. Its presence in air reduces the rate of combustion. Due to its inertness, it is also used to preserve food. Life would not have been possible in the absence of non-metals like carbon, oxygen, nitrogen and hydrogen.

*Non-metals are the elements which form negative ions by the gain of electrons.*

**For example :** Chlorine, oxygen and nitrogen are non-metals because they form negative ions by gain of 1, 2 and 3 electrons respectively.



The number of electrons lost or gained by an element is equal to its **valency**.

Metals constitute the mineral wealth of a country. The major metals in the earth's crust in the decreasing order of their abundance are aluminium, iron, calcium, sodium, potassium and magnesium. The major non-metals in the earth's crust in the decreasing order of their abundance are oxygen, silicon, phosphorus and sulphur.

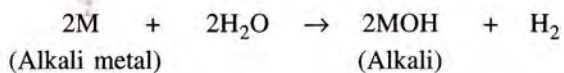
## 7.4 CATEGORISATION OF METALS

The metals have been categorised on the basis of their characteristics as given below.

### 7.4.1 Alkali Metals

The elements such as lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs) and francium (Fr) have one electron in their outermost orbit and show one valency. So they are placed in IA group (the first column on the left) of the Periodic Table. They are known as alkali metals, as *they react with water to form their hydroxides which are strong alkalies.*



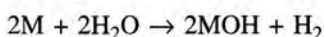


Where M is any metal of IA group.

Hydrogen is placed in this group as it has one electron, but it is not an alkali metal.

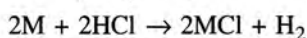
### Characteristics

- Occurrence** : All of them are very reactive and do not occur in free state.
- Nature** : They are soft (can be cut with a knife) and have low melting and boiling points.
- Bonding** : All alkali metal salts (except some salts of lithium) are ionic in nature.
- Action of air** : They react rapidly with oxygen and water vapour in the air. *Reactivity of these metals increases down the group.*
- Action of water** : They react violently with water and produce hydrogen.



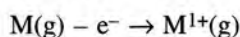
(Any Alkali metal)

- Action of acids** : They react violently with dil HCl and dil.  $H_2SO_4$ , to produce hydrogen



(Any Alkali metal)

- They have low ionisation energy and form unipositive ion easily.



They are strong **reducing agents**.

- When freshly cut, they show typical silvery white metallic lustre but soon they turn dull (tarnish) because of their reaction with air.
- All alkali metal salts impart colour to the flame, e.g., lithium (*crimson red*), sodium (*golden yellow*), potassium (*pale violet*).
- Alkali metals are obtained by electrolysis of their molten salts.

### 7.4.2 Alkaline Earth Metals

The elements such as beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra) are known as alkaline earth metals, because their oxides occur in the earth's crust and their hydroxides are alkalies.

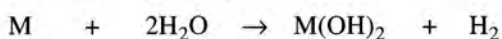
All the elements of this group have two electrons in their outermost orbit and show the valency two, so they are placed in **IIA group** of the Periodic Table.

### Characteristics

- Occurrence** : They are reactive metals (less reactive than alkali metals); hence they do not occur in free state in nature.
- Nature** : They are greyish white in colour and harder than the alkali metals.
- Bonding** : All the alkaline earth metal salts except beryllium are ionic compounds.
- Action of air** : They are less reactive than alkali metals.

Their reactivity increases on moving down the group.

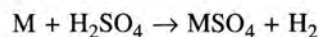
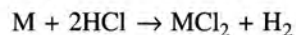
- Action of water** : They react with water to produce hydrogen.



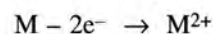
(Any alkaline metal)

(Alkali)

- Action of acids** : They react with dil HCl and dil  $H_2SO_4$  to produce hydrogen.



- They have low ionisation energy (higher than alkali metals) and form dipositive ion.



They are also strong **reducing agents**.

- Melting points and boiling points are comparatively low but these are higher than the alkali metals.
- Except beryllium and magnesium, all other alkaline earth metals impart colour to the flame like calcium-*brick red*, strontium-*crimson*, barium-*apple green* and radium-*crimson*.
- They are obtained by electrolysis of their molten salts.

### 7.4.3 Transition metals\*

They are placed in the middle of the Periodic Table (group 3 to group 12). Their two outermost

\* Not in syllabus



shells are incomplete. Examples are iron, zinc, copper, mercury.

**Characteristics**

- (a) All these elements are metals with high melting and boiling points.

- (b) They are good conductors of heat and electricity.
- (c) Some of these elements are attracted towards a magnet.
- (d) Most of these elements are used as catalysts.

**TABLE 7.1 : THE LONG FORM OF PERIODIC TABLE OF ELEMENTS**

Periods	s - block		d - block										p - block						Noble gas									
	IA	IIA	IIIB	IVB	VB	VIB	VII B	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	Zero												
1	1 H Hydrogen	2 He Helium											3 Li Lithium	4 Be Beryllium	5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon								
2	3 Li Lithium	4 Be Beryllium											11 Na Sodium	12 Mg Magnesium	13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulphur	17 Cl Chlorine	18 Ar Argon								
3	11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulphur	17 Cl Chlorine	18 Ar Argon	19 K Potassium	20 Ca Calcium								
4	19 K Potassium	20 Ca Calcium											21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium											39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Caesium	56 Ba Barium											57-71 Lanthanide Series	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
7	87 Fr Francium	88 Ra Radium											89-103 Actinide Series	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Uut Ununtrium	114 Fl Flerovium	115 Uup Ununpentium	116 Lv Livermorium	117 Uus Ununseptium	118 Uuo Ununoctium

Block	Group	Element	Atomic Number	Symbol	State
s-block	IA	H	1	H	Gas
	IA	Li	3	Li	Solid
	IA	Na	11	Na	Solid
	IA	K	19	K	Solid
	IA	Rb	37	Rb	Solid
	IA	Cs	55	Cs	Solid
	IA	Fr	87	Fr	Solid
	IIA	Be	4	Be	Solid
	IIA	Mg	12	Mg	Solid
	IIA	Ca	20	Ca	Solid
d-block	VIII	Fe	26	Fe	Solid
	VIII	Ni	28	Ni	Solid
	VIII	Cu	29	Cu	Solid
	VIII	Zn	30	Zn	Solid
	VIII	Co	27	Co	Solid
	VIII	Ni	28	Ni	Solid
	VIII	Cu	29	Cu	Solid
	VIII	Zn	30	Zn	Solid
	VIII	Ag	47	Ag	Solid
	VIII	Cd	48	Cd	Solid
p-block	VIIA	F	9	F	Gas
	VIIA	Cl	17	Cl	Gas
	VIIA	Br	35	Br	Liquid
	VIIA	I	53	I	Solid
	VIIA	At	85	At	Solid
	VIA	O	8	O	Gas
	VIA	S	16	S	Solid
	VIA	Se	34	Se	Solid
	VIA	Te	52	Te	Solid
	VIA	Po	84	Po	Solid
f-block	Lanthanide Series	La	57	La	Solid
	Lanthanide Series	Ce	58	Ce	Solid
	Lanthanide Series	Pr	59	Pr	Solid
	Lanthanide Series	Nd	60	Nd	Solid
	Lanthanide Series	Pm	61	Pm	Solid
	Lanthanide Series	Sm	62	Sm	Solid
	Lanthanide Series	Eu	63	Eu	Solid
	Lanthanide Series	Gd	64	Gd	Solid
	Lanthanide Series	Tb	65	Tb	Solid
	Lanthanide Series	Dy	66	Dy	Solid
actinide series	Actinide Series	Th	90	Th	Solid
	Actinide Series	Pa	91	Pa	Solid
	Actinide Series	U	92	U	Solid
	Actinide Series	Np	93	Np	Solid
	Actinide Series	Pu	94	Pu	Solid
	Actinide Series	Am	95	Am	Solid
	Actinide Series	Cm	96	Cm	Solid
	Actinide Series	Bk	97	Bk	Solid
	Actinide Series	Cf	98	Cf	Solid
	Actinide Series	Es	99	Es	Solid

Elements with atomic number 110 and above have been reported but not yet fully authenticated and named. As of 2005, the table contains 116 chemical elements whose discoveries have been confirmed; 94 are found naturally on earth and the rest are synthetic elements.



- (e) Most of these elements exhibit variable valencies.

#### 7.4.4 Inner transition metals\*

They are placed at the bottom of the Periodic Table. Their actual place is in the third column, *i.e.*, Group III B and the sixth period (called lanthanides) and the seventh period (called actinides) of the Periodic Table.

#### Characteristics

- They are heavy metals with high melting and boiling points.
- They show variable valencies.
- They form coloured ions.
- Some inner transition metals *i.e.* actinides are radioactive by nature.

Certain elements which show properties of both metals and non-metals are called **metalloids** or **semi-metals**.

\* Not in syllabus

They are : Boron (B), Silicon (Si), Germanium (Ge), Arsenic (As), Antimony (Sb), Tellurium (Te) and Polonium (Po).

#### 7.5 POSITION OF METALS AND NON-METALS IN THE PERIODIC TABLE

The metals have been placed on the left side (Group IA and IIA) and in the middle of the Periodic Table (Group IB to VII B and Group VIII), whereas non-metals have been placed on the right side of the Periodic Table. Elements in Group IIIA (except Boron) are metals and their metallic nature increases on moving down the group. Elements of Group IVA, VA, VIA and VIIA are mostly non-metallic, though a few elements at the bottom of the group show some metallic nature. Only *one non-metal, i.e., hydrogen [H] has been placed on the left side of the Periodic Table.*

The metals and non-metals in the Periodic Table are separated by a zig-zag line of metalloids.

#### 7.6 COMPARISON OF METALS AND NON-METALS (GENERAL PROPERTIES)

Metals	Non-metals
<p><b>A. Physical properties</b></p> <ol style="list-style-type: none"> <li><b>Physical State :</b> All metals are solids at room temperature <b>except mercury</b> (<i>which is a liquid</i>) and <b>gallium</b> (<i>which changes to liquid when handled</i>).</li> <li><b>Lustre :</b> Metals possess a high lustre (called metallic lustre). They can be polished to give a highly reflective surface (in case of sodium and potassium, this lustre lasts for a very short time). <b>Lead is a metal with dull appearance.</b></li> <li><b>Hardness :</b> Most of the metals are hard and strong. (<b>Exceptions : sodium and potassium</b> can be <i>cut with a knife</i>).</li> <li><b>M.P. and B.P. :</b> Usually, metals possess high melting and boiling points and vaporise only at high temperatures (<b>Exceptions : gallium, mercury, sodium and potassium</b>).</li> <li><b>Density :</b> Metals have a high density (<b>Exceptions : sodium and potassium</b> are less dense than water).</li> </ol>	<ol style="list-style-type: none"> <li>Non-metals exist in all the three states. Eleven non-metals are gases; only <b>bromine</b> is a <b>liquid</b> non-metal and others are solids.</li> <li>Non-metals have a dull appearance, <b>except iodine and graphite</b> whose crystals are quite lustrous.</li> <li>Some solid non-metals (like sulphur and phosphorus) are soft; whereas some are hard. Carbon in the form of <b>diamond is the hardest substance known.</b></li> <li>The melting and boiling points of non-metals are low. They vaporise at low temperatures, (<b>Exceptions : carbon, boron and silicon</b>).</li> <li>Non-metals have low densities. Density of iodine is higher than that of many metals. Diamond has a high density.</li> </ol>



- Ductility** : Metals are usually ductile. In other words they can be drawn into thin wires without breaking. Silver wires of 0.0008 mm diameter have been drawn; tungsten can be drawn into such fine wires that are almost invisible (*Exceptions* : zinc, mercury and gallium).
- Malleability** : Metals are usually malleable, *i.e.*, can be beaten into thin sheets without cracking (*except zinc and mercury*). Silver and gold are highly malleable. Gold has been beaten into foil less than 0.0001 mm in thickness.
- Brittleness** : Metals are hard but not brittle (*Exception* : Zinc).
- Conduction of heat and electricity** : Metals are good conductors of heat and electricity ; silver and copper excel in this property. (*Exception* : tungsten).
- Alloys and Amalgams** : They form alloys and amalgams.
- Solubility** : Usually, metals do not dissolve in liquid solvents.

## B. Chemical Properties

- Valence Electrons (electronic configuration)** : Atoms of metals usually have 1, 2 or 3 electrons in their outermost shell. The less is the number, the more active is the metal.
- Formation of ions** : Metals form +ve ions (or cations) by loss of electrons; they are electropositive.
 
$$\text{Na} - e^- \rightarrow \text{Na}^+$$

$$\text{Mg} - 2e^- \rightarrow \text{Mg}^{2+}$$

$$\text{Al} - 3e^- \rightarrow \text{Al}^{3+}$$

The number of electrons lost is the valency of the metal.
- Discharge of ions** : These are discharged at the cathode during the electrolysis of their compounds.  
*At cathode* :  $\text{Na}^+ + 1e^- \rightarrow \text{Na}$   
                   cation                                  neutral atom
- Atomicity** : Molecules of metals in vapour state are usually monoatomic.
- Nature of oxides** : Oxides of metals are usually basic. Soluble basic oxides dissolve in water forming an *alkaline solution*; metallic oxides are *electrovalent*.

- Non-metals are not ductile **except carbon fibre**.
- Non-metals are not malleable in solid form *i.e.* they break into pieces when hammered.
- Non-metals are generally brittle, *i.e.*, they break when force is applied.
- Non-metals are non-conductors of heat and electricity (only carbon in the form of *gas-carbon* and *graphite* conducts electricity).
- They do not form alloys and amalgams. (*Exceptions: carbon and phosphorus* can be used in alloys).
- Non-metals dissolve in many liquid solvents, *e.g.*, sulphur dissolves in carbon disulphide and iodine in chloroform.

- Atoms of non-metals usually have 5, 6 or 7 electrons in their outermost shell. The more is the number, the more active is the non-metal. (*Exception is hydrogen*).
- Non-metals form -ve ions (or anions) by gain of electrons; they are electronegative.
 
$$\text{Cl} + e^- \rightarrow \text{Cl}^-$$

$$\text{O} + 2e^- \rightarrow \text{O}^{2-}$$

$$\text{N} + 3e^- \rightarrow \text{N}^{3-}$$

The number of electrons gained is the valency of the non-metal (**Exception is hydrogen which generally forms positively charged cation, H<sup>+</sup>**).
- Non-metals are liberated at the anode during electrolysis. (**Exception: Hydrogen as H<sup>+</sup> ions are liberated at the cathode**).  
*At anode* :  $\text{Cl}^- - 1e^- \rightarrow \text{Cl}$   
                   anion                                  neutral atom  
 $\text{Cl} + \text{Cl} \rightarrow \text{Cl}_2$
- Molecules of non-metals in the vapour state are usually polyatomic. (*Exception* : Inert gases).
- Oxides of non-metals are usually **acidic**. Soluble acidic oxides dissolve in water forming an *acidic solution*; non-metallic oxides are *covalent*.

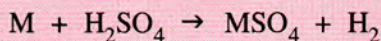
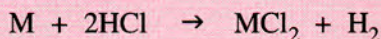


**Basic oxides:**  $\text{Na}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{CuO}$ .

**Amphoteric oxides :**  $\text{Al}_2\text{O}_3$ ,  $\text{PbO}$ ,  $\text{ZnO}$

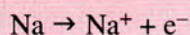
**Acidic oxides :**  $\text{CrO}_3$ ,  $\text{Mn}_2\text{O}_7$

6. **Reaction with acids :** Metals above hydrogen in the activity series usually *replace hydrogen from dilute non-oxidising acids* (hydrochloric and sulphuric acids);



7. **Nature of chlorides :** Metallic chlorides are electrovalent (ionic) compounds. They are electrolytes. When electricity is passed through fused or aqueous solution of metallic chloride, metals are discharged at the cathode and chlorine at the anode.

8. **Oxidising and reducing property :** They ionise by loss of electrons and hence are reducing agents.



9. **Nature of hydrides :** Metals do not form hydrides. But if they form, they are **not very stable**, e.g.,  $\text{NaH}$  (sodium hydride) and  $\text{CaH}_2$  (calcium hydride).

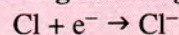
**Acidic oxides:**  $\text{CO}_2$ ,  $\text{SO}_2$ ,  $\text{SO}_3$ ,  $\text{NO}_2$ ,  $\text{P}_2\text{O}_5$ .

**Neutral oxides :**  $\text{CO}$ ,  $\text{NO}$ ,  $\text{N}_2\text{O}$ ,  $\text{H}_2\text{O}$ .

6. Non-metals do not react with dil. hydrochloric acid or sulphuric acid.

7. Non-metallic chlorides are covalent compounds and are non-electrolytes. *For example*,  $\text{CCl}_4$  and  $\text{HCl}$ .

8. They ionise by gain of electrons and hence are oxidising agents. (**Exception : Carbon and hydrogen are strong reducing agents**).



9. Non-metals form quite stable hydrides., e.g.,  $\text{CH}_4$ , (methane),  $\text{H}_2\text{O}$  (water) and  $\text{NH}_3$  (ammonia).

## EXERCISE-7A

- Name the three classes in which elements are classified. Which was the first metal used by man ?
  - Name the metal and non-metal present in abundance in the earth crust.
- Name the metal which is a constituent of :
  - blood pigment,
  - plant pigment.
- Give the importance of the following in living beings :
  - Nitrogen,
  - Hydrogen,
  - Carbon.
- State the position of the following in the Periodic Table :
  - Alkali metals,
  - Alkaline earth metals,
  - Iron and zinc,
  - Aluminium.
- Give the general characteristics of :
  - Alkali metals,
  - Alkaline earth metals with reference to
    - bonding
    - action of air
    - action of water
    - action of acid.
- Name :
  - a liquid non-metal,
  - a metal with dull appearance,
  - a metal with low melting and boiling points,
  - a non-metal with very high m.p. & b.p.,
  - a metal which can float on water,
  - a metal which can be cut with a knife,
  - a metal which is a bad conductor of heat and electricity,
  - a non-metal which is ductile,
  - a non-metal used in alloys,
  - a non-malleable metal.
  - two metalloids
- Distinguish between metals and non-metals on the basis of :
  - ion formation,
  - discharge of ions,
  - nature of oxide formed,
  - oxidising and reducing property,
  - reaction with acids.
- Complete :
  - $\text{Na} - \dots \rightarrow \text{Na}^+$
  - $\text{N} + \dots \rightarrow \text{N}^{3-}$
  - $\text{Cl} + \text{e}^- \rightarrow \dots$
  - $\text{Mg} - \dots \rightarrow \text{Mg}^{2+}$
  - $\text{M} + \text{HCl} \rightarrow \text{MCl}_2 + \dots$
  - $\text{Mg} + \text{H}_2\text{SO}_4 \rightarrow \dots + \dots$



9. Select from the following list :

Fe<sub>2</sub>O<sub>3</sub>, NO, PbO, Mn<sub>2</sub>O<sub>7</sub>.

- (a) Basic oxide .....
- (b) Amphoteric oxide .....
- (c) Acidic oxide .....
- (d) Neutral oxide .....

10. Take an element from an alkali metal and one from an alkaline earth metal and write an equation for their action with :

- (a) Hydrochloric acid, (b) Oxygen,
- (c) Sulphuric acid, (d) Water.

11. (a) The table below compares some properties of metals and non-metals. Write down the missing statements (i) to (iv) :

METALS	NON-METALS
(i) .....	Poor conductors of heat.
(ii) Malleable	.....
(iii) Form positive ions	.....
(iv) .....	Form acidic oxides.

- (b) How many valence electrons are present in :  
 (i) metals and (ii) non-metals ?

## 7B. 'STUDY OF ACTIVITY SERIES OF METALS

### 7.7 THE ACTIVITY SERIES OF METALS

Metals differ in tendency to lose valence electrons and can be arranged in a series.

The arrangement of metals in the decreasing order of their reactivity is called the *activity* or *reactivity* series of the metals.

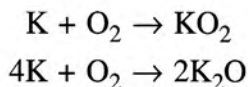
The metal potassium is kept at the top of the series because it is most reactive. Also it is most electropositive as it easily oxidises, *i.e.*, gives up valence electrons. The least active metal is gold which is placed at the bottom of the list.

*Hydrogen, though a non-metal, has been included in this series because it can form a positive ion. It would occupy the position based on its formation of the positive ion.*

#### Main Points of the Activity Series

- (i) The electropositive character decreases on moving down the series.

Potassium and sodium react with oxygen at normal temperature, and burn when heated, forming superoxide and if oxygen is in limited supply, then their oxide is formed.

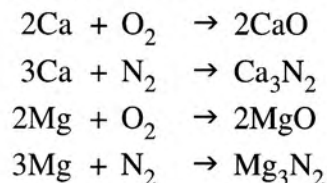


K  
Na  
Ca  
Mg  
Al  
Zn  
Fe  
Pb  
[H]  
Cu  
Hg  
Ag  
Au

↓

Metal	Oxides formed
<b>Ca</b>	2Ca + O <sub>2</sub> → 2CaO
<b>Mg</b>	2Mg + O <sub>2</sub> → 2MgO
<b>Al</b>	<b>Forms oxide at ordinary temperature :</b> 4Al + 3O <sub>2</sub> → 2Al <sub>2</sub> O <sub>3</sub> <b>The metals listed below form oxides on strong heating :</b>
<b>Zn</b>	2Zn + O <sub>2</sub> → 2ZnO
<b>Fe</b>	3Fe + 2O <sub>2</sub> → Fe <sub>3</sub> O <sub>4</sub>
<b>Pb</b>	2Pb + O <sub>2</sub> → 2PbO
<b>[H]</b>	
<b>Cu</b>	2Cu + O <sub>2</sub> → 2CuO 4Cu + O <sub>2</sub> → 2Cu <sub>2</sub> O
<b>Hg</b>	2Hg + O <sub>2</sub> → 2HgO
<b>Ag</b>	Oxides are not formed even on strong heating.
<b>Au</b>	

**Note :** Metals like calcium and magnesium have no action with air at ordinary temperature. On burning, they form oxides and nitrides.



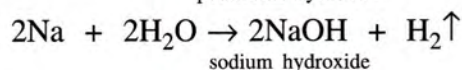
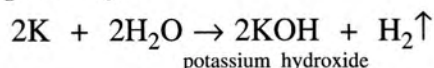


(ii) The reducing power of metals increases on moving down the series. Thus, potassium is the strongest reducing agent.

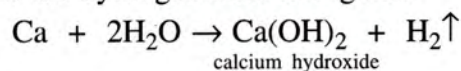
(iii) The tendency of metals to lose valence electrons *i.e.*, tendency of metals to get oxidised decreases on moving down the series. Thus, potassium gets most readily oxidised.

(iv) The ability of the metals to reduce water to hydrogen decreases in passing down the series.

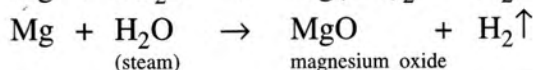
*Potassium and sodium* reacts vigorously with cold water and the hydrogen produced during the reaction gets ignited by the heat evolved during the reaction, producing lilac flame and golden yellow flame respectively.



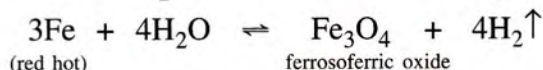
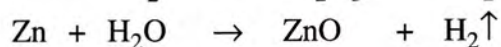
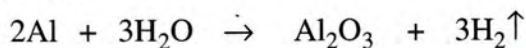
*Calcium* : Reacts fairly vigorously with cold water but the hydrogen does not ignite.



*Magnesium* : Reacts very slowly with water, vigorously with warm water and burns in steam to give hydrogen.



*Aluminium, zinc and iron* : Reacts with steam when hot.



(v) All the metals above hydrogen, in the activity series, **reduce hydrogen ions from dil. HCl or dil. H<sub>2</sub>SO<sub>4</sub> and give out hydrogen.**

The rate of reaction decreases on moving from potassium (violent reaction) to lead (hardly any reaction) in the activity series.

*The reaction of dilute acids with lead is very slow, because the salts lead chloride and lead*

Metals	Reaction with acid
<b>K</b>	Reacts explosively with dilute acid liberating hydrogen.
<b>Na</b>	$2\text{Na} + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2$
<b>Ca</b>	Calcium reacts less vigorously $\text{Ca} + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2$
<b>Mg</b>	Reacts with dilute acids less vigorously, liberating hydrogen. $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$
<b>Al</b>	Due to great affinity towards oxygen, a coating of oxide is formed, which does not allow any further reaction with acid.
<b>Zn</b>	$\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$
<b>Fe</b>	$\text{Fe} + 2\text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2$
<b>Pb</b>	Lead reacts with conc. HCl to liberate hydrogen $\text{Pb} + 2\text{HCl} \rightarrow \text{PbCl}_2 + \text{H}_2$
<b>[H]</b>	
<b>Cu</b>	
<b>Hg</b>	
<b>Ag</b>	Do not produce hydrogen on reaction with dilute or conc. acids.
<b>Au</b>	

*sulphate formed are sparingly soluble in dilute acids. During the reaction, the chloride or sulphate gets coated on the metal and prevents reaction to proceed further.*

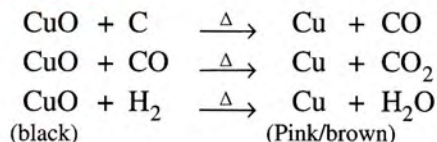
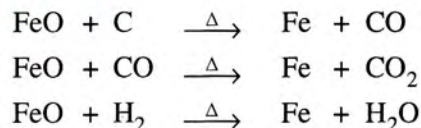
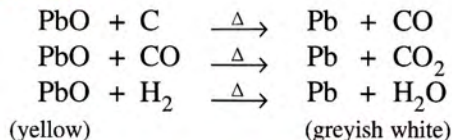
(vi) Any metal higher up in the series displaces the metal below it from the salt solutions of the latter.

The larger the difference in the positions of the metals in the series, more rapidly does the displacement occur.

(vii) **Reduction of metallic oxides** : Oxides of metals like K, Na, Ca, Mg and Al cannot be reduced by common reducing agents like H<sub>2</sub>, CO or C.

However, metal oxides below aluminium can be reduced by heating in the presence of **reducing agents.**



**Copper oxide****Iron (II) oxide****Lead oxide**

For detailed study of reduction of metallic oxides refer to the topic "Extraction of metals" given ahead in this chapter.

**7.7.1 Action of heat on some metallic compounds**

Oxides	Hydroxides	Carbonates	Nitrates
K, Na, Ca, Mg, Al Oxides of metals from potassium to aluminium are stable to heat and so can be reduced only by electrolysis.	K, Na, Ca, Mg, Al Metal hydroxides are stable to heat and are soluble in water. Decompose on heating to form metal oxide and water vapour.	K, Na, Ca, Mg, Al, Zn, Fe, Pb, Cu Stable to heat and soluble in water. Decompose on heating with decreasing vigour to form the metal oxide and carbon dioxide. $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$ $\text{ZnCO}_3 \rightarrow \text{ZnO} + \text{CO}_2$ $\text{CuCO}_3 \rightarrow \text{CuO} + \text{CO}_2$	K, Na, Ca, Mg, Al, Zn, Fe, Pb, Cu On heating metal, nitrite and oxygen are formed. $2\text{KNO}_3 \rightarrow 2\text{KNO}_2 + \text{O}_2$ Decompose on heating to form the metal oxide, nitrogen dioxide and oxygen. $2\text{Ca(NO}_3)_2 \rightarrow 2\text{CaO} + 4\text{NO}_2 + \text{O}_2$ $2\text{Zn(NO}_3)_2 \rightarrow 2\text{ZnO} + 4\text{NO}_2 + \text{O}_2$ $2\text{Pb(NO}_3)_2 \rightarrow 2\text{PbO} + 4\text{NO}_2 + \text{O}_2$ $2\text{Cu(NO}_3)_2 \rightarrow 2\text{CuO} + 4\text{NO}_2 + \text{O}_2$
Zn, Fe, Pb, Cu Zinc oxide can be reduced by coke only. Oxides of iron, lead and copper are reduced by C, CO, H <sub>2</sub> , NH <sub>3</sub> .	Zn, Fe, Pb, Cu $\text{Ca(OH)}_2 \rightarrow \text{CaO} + \text{H}_2\text{O}$ $\text{Zn(OH)}_2 \rightarrow \text{ZnO} + \text{H}_2\text{O}$ $\text{Pb(OH)}_2 \rightarrow \text{PbO} + \text{H}_2\text{O}$ $\text{Cu(OH)}_2 \rightarrow \text{CuO} + \text{H}_2\text{O}$	Hg, Ag Forms the metal, oxygen and carbon dioxide. $2\text{Ag}_2\text{CO}_3 \rightarrow 4\text{Ag} + \text{O}_2 + 2\text{CO}_2$	Hg, Ag Forms metal, nitrogen dioxide and oxygen. $2\text{AgNO}_3 \xrightarrow{\Delta} 2\text{Ag} + 2\text{NO}_2 + \text{O}_2$
Hg, Ag Oxides of mercury and silver decompose to give metal and oxygen. $2\text{Ag}_2\text{O} \xrightarrow{\Delta} 4\text{Ag} + \text{O}_2$	Hg, Ag Yields metal, oxygen and water vapour. $4\text{AgOH} \rightarrow 4\text{Ag} + \text{O}_2 + 2\text{H}_2\text{O}$		

**7.8 CORROSION**

It has been observed that the surface of many metals, which is in direct contact of the atmosphere, starts reacting with the components of the atmosphere such as air, moisture and gases.

The compounds so formed on the surface of the metal, are generally porous and gradually fall off from the surface of the metal, thus exposing the inner layers of the metal underneath to the attack by atmospheric air and moisture.

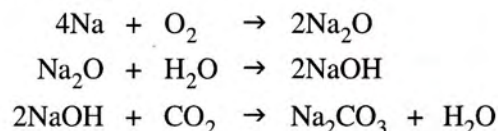
When the surface of a metal is attacked by air, moisture or any other substance around it, the metal is said to corrode and the phenomenon is known as **corrosion**.

In such a process, mostly metal oxides are formed, but if metals contain impurities like sulphur

and carbon, they may lead to the formation of sulphides and carbonates as well.

**The effects of corrosion based on the activity series are as follows :**

- (i) **Alkali metals** like sodium and potassium react with air to form oxides. *These react with water present in air to yield hydroxides which slowly absorb carbon dioxide of the air to form carbonates.*



Reactive metals like sodium and potassium are kept in kerosene oil as they easily react with moisture and air.

- (ii) **Aluminium** and **magnesium** form white colour oxide on exposure to atmosphere.



- (iii) **Iron** forms hydrated oxide which is **brown** in colour known as rust ( $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ ).
- (iv) A **white deposit** is formed on the surface of **lead** when it comes in contact with moist air. It is a mixture of lead hydroxide and lead carbonate called basic lead carbonate [ $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$ ].
- (v) **Copper** forms a **green deposit on its surface** when exposed to moist air. It is a mixture of copper hydroxide and copper carbonate (basic copper carbonate) [ $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ ].
- (vi) **Silver** gets **tarnished** when exposed to the atmosphere which contains pollutant  $\text{H}_2\text{S}$  and forms a **black** coating of  $\text{Ag}_2\text{S}$ .

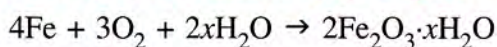
The noble metals such as gold and platinum do not corrode easily.

### 7.8.1 Corrosion of Iron

#### Corrosion of iron is known as RUSTING

*Rusting is the slow oxidation of iron by atmospheric oxygen in the presence of water.*

Iron when comes in contact with moist air reacts to give rust which is a **brown powder mainly hydrated iron (III) oxide** ( $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ ).



Rust is a soft powdery material, which easily falls off from the surface of iron and hence it further exposes the inner part of the iron metal to air and moisture for further rusting. Thus, iron gets damaged.

It is a wasteful reaction. It may lead to collapse of bridges, buildings, leakage of roofs and other harmful consequences.

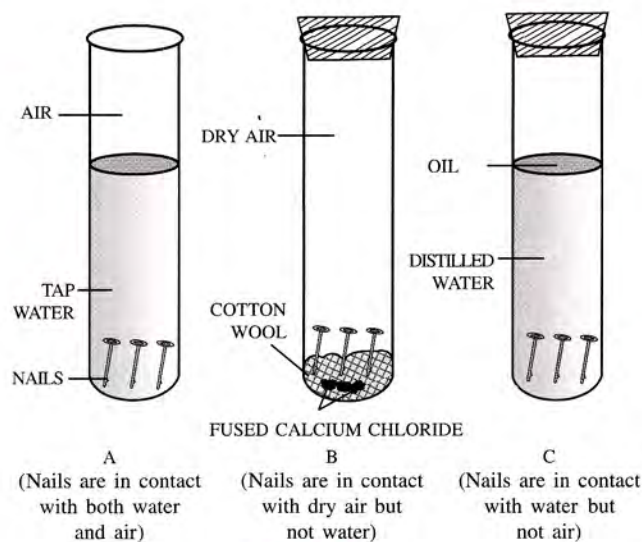
**Note :** 1. Rusting differs from tarnishing of metals; tarnishing is the oxidation of the metallic surfaces other than iron. The oxide so formed does not flake off, but sticks to the metal surface. Thus after tarnishing further oxidation stops.

2. Cast iron or pig iron contains carbon and other impurities. It gets rusted slower than steel which has less carbon content.

#### Activity : To prove that air and water are necessary for corrosion (i.e., rusting) of iron.

Polish some iron nails with an emery cloth until they shine. Emery cloth removes rust and grease from metals when it is rubbed on them. Place the nails in test tubes under different conditions, as outlined below :

- (a) Put some nails in a test tube and cover them with distilled water. Close the test tube with a cork to stop the water from evaporating. These nails are in contact with both air and water.
- (b) Keep some anhydrous calcium chloride at the bottom of the second test tube and cover it with cotton wool. (Calcium chloride is able to absorb all the moisture from the air). Place the bright nails on top and cork the tube. These nails are thus in contact with only dry air.



- (c) Boil some water to expel the dissolved air from it. Pour some of it on to the three bright nails kept in the third test tube. To prevent the air in the tube from dissolving in the water again as soon as it cools, a layer of vaseline or oil is poured on top of the water. These nails are thus in contact with only water.
- (d) Leave the test tubes for some days and then find out which nails have rusted. Find out what are the conditions for rusting ?



## 7.8.2 Factors favourable for increased corrosion

In addition to the **presence of oxygen** and **moisture** it is noticed that

1. Metals which are placed higher in the activity series, corrode more easily.
2. Dissolved salts in water act as electrolyte and enhance the rate of corrosion (iron corrodes fast in sea water).
3. The presence of a metal which is less reactive than iron increases the rate of rusting of iron, since it will favour the more reactive metal like iron to lose electrons and get oxidised. Due to this reason **galvanisation** (coating of zinc) is preferred to tinning in the prevention of rusting of iron.
4. The presence of pollutants like  $\text{NO}_2$  and  $\text{CO}_2$  increases rusting.

## 7.8.3 Prevention of corrosion

The rusting of iron can be prevented by oiling, greasing, painting, galvanising, chrome-plating, anodising or making alloys. These methods can be classified into three categories

1. **Barrier protection** : When metal surface is not allowed to come in contact with atmospheric agents like air, water then process is known as Barrier Protection process. It is done by
  - (i) Coating the metal (Iron) with another metal with the help of electricity (**electroplating**).
  - (ii) Prevention by painting the metal (Iron) so that the iron do not come in contact with atmospheric reagents.
  - (iii). By covering the metal (Iron) by grease or oil or antirust solution.

2. **Sacrificial protection** : The metal to be protected is covered with more electropositive metal like zinc, magnesium, etc., which gets oxidised and saves the metal.

*For example*, Iron is coated with zinc and the process is known as **GALVANISATION**.

3. **Cathode protection** : The object to be saved (iron) from rusting is connected to a piece of more electropositive metal like **zinc**, magnesium or aluminium, by a piece of wire. The anode is made of more reactive element like zinc, which loses electrons and get oxidised and goes on disappearing thus saves the cathode (iron) from rusting (**GALVANISATION**).

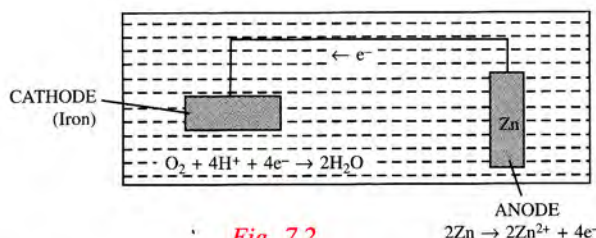


Fig. 7.2

This method is usually used for protecting iron objects like sewer pipes and storage tanks which are buried underground.

## 7.8.4 Advantage of corrosion

Sometimes corrosion of metals is an advantage as it prevents the metal underneath from further damage.

*For example*, on exposure to air, the surface of metals like aluminium and zinc forms layers of their oxides which are very sticky and impervious in nature, and hence act as a **protective layer**. This layer protects the metal from further damage. Thus the articles made up of aluminium, do not corrode easily.

## EXERCISE-7B

1. Name :

- (a) two metals which are liquid at room temperature,
- (b) metal which do not corrode easily
- (c) a metal which lacks ductility,

- (d) a non-metal which is lustrous,
- (e) a non-metal which conducts electricity,
- (f) a metal which is brittle,
- (g) two elements which are monoatomic,



- (h) two metallic oxides which are acidic,  
 (i) two metallic oxides which are amphoteric,  
 (j) two metals which react with cold water,  
 (k) the compound responsible for green deposit on the surface of copper,  
 (l) a non-metal which can form a positive ion,  
 (m) a non-metal which shows reducing property,  
 (n) a metal whose oxide is reduced only by carbon.
2. Explain how the activity series accounts for each of the following :
- (a) occurrence of metals,  
 (b) tendency to corrosion,  
 (c) reaction with water,  
 (d) reaction with acids.
3. Give the balanced reactions for the following :
- (a) Sodium is dropped in water,  
 (b) Magnesium reacts with boiling water,  
 (c) Red hot iron reacts with steam,  
 (d) Iron reacts with dilute HCl.
4. (a) Why are alkali metals kept in kerosene oil ?  
 (b) What is :  
 (i) basic lead carbonate and  
 (ii) brown powder deposit on iron ?  
 (c) Why is hydrogen kept in the metal activity series ?
5. Metal A has an electronic configuration of 2, 8, 1 and metal B has 2, 8, 8, 2 which is a more reactive metal.  
 (a) Identify A and B and give their reactions with dil. HCl and dil.  $H_2SO_4$ .  
 (b) Give the effect of heat on their :  
 (i) oxides, (ii) hydroxides,  
 (iii) carbonates, (iv) nitrates.
6. (a) What is corrosion ? What are necessary conditions for corrosion ?  
 (b) State under what conditions corrosion is faster.  
 (c) Corrosion can be an advantage in some case. Explain.
7. (a) What is rust ? Give the equation for the formation of rust.  
 (b) State two conditions necessary for rusting of iron.  
 (c) How does the painting of an iron object prevent rusting ?
8. What is galvanisation ? How does it protect iron from rusting ?
9. A student has been collecting silver coins and copper coins. One day she observed a black coating on silver coins and a green coating on copper coins. Which chemical phenomenon is responsible for these coatings ? Write the names of black and green coatings.
10. Aluminium is said to be more reactive than iron, towards oxygen (or air). Yet iron undergoes corrosion to a greater extent than aluminium. Explain.
11. Why do gold ornaments look new even after several years of use ?
12. From the metals : copper, iron, magnesium, sodium, and zinc, select a different metal in each case which :  
 (a) does not react with dilute hydrochloric acid,  
 (b) can form 2 + and 3 + ions,  
 (c) has a hydroxide that reacts with both acids and alkalis,  
 (d) does not react with cold water but reacts with steam when heated.  
 (e) Arrange the above metals in the decreasing order of reactivity.

## 7C. EXTRACTION OF METALS BASED ON THE ACTIVITY SERIES

### 7.9 OCCURRENCE OF METALS

Most of the metals are reactive so they occur in combined state in the form of their oxides, carbonates, halides, sulphides, sulphates, etc. mixed with mud, clay, sand and stone.

Since the reactivity series lists the metals in the decreasing order of electropositivity, it might

be expected that those at the top would combine with more electronegative elements in their minerals. *For example*, sodium and potassium occur mainly as their chlorides, calcium and magnesium as carbonates, aluminium as its oxide while zinc, lead, copper, mercury and silver are found as sulphides.



Metals	Main Ores
<b>K</b>	Carnallite $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$
<b>Na</b>	Rock salt $\text{NaCl}$ (in sea water)
<b>Ca</b>	Limestone, Marble ( $\text{CaCO}_3$ ), Calcium sulphate dihydrate ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ), Gypsum $\text{CaSO}_4$
<b>Mg</b>	Carnallite, magnesium carbonate $\text{MgCO}_3$ (Magnesite)
<b>Al</b>	Bauxite $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ Cryolite $\text{Na}_3\text{AlF}_6$
<b>Zn</b>	Zinc blende $\text{ZnS}$ Calamine $\text{ZnCO}_3$
<b>Fe</b>	Red Haematite $\text{Fe}_2\text{O}_3$ Brown haematite $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$
<b>Pb</b>	Galena $\text{PbS}$
<b>Cu</b>	Copper pyrites $\text{CuFeS}_2$
<b>Hg</b>	Cinnabar $\text{HgS}$
<b>Ag</b>	Argentite $\text{Ag}_2\text{S}$ Horn silver $\text{AgCl}$

**Note :** Insoluble ores are found as rocks while soluble ones like alkali chloride are found in sea water.

Metals which have low chemical reactivity are found in free state. Gold and platinum are found in free state (native state).

### COMMON TERMS USED IN EXTRACTION

#### (i) Metallurgy :

The process used for the extraction of metals in their pure form from their ores is referred to as **Metallurgy**.

*Metallurgy deals with the production and purification of metals and manufacture of alloys.*

#### (ii) Minerals :

The naturally occurring compounds of metals which are generally mixed with other matter such as soil, sand, limestone and rocks are known as **minerals**.

#### (iii) Gangue (Matrix) :

Earthly impurities including silica ( $\text{SiO}_2$ ), mud, etc., associated with the ore are called **gangue** or **matrix**.

#### (iv) Ores :

Those minerals from which the metals are extracted commercially at a comparatively low cost and with minimum effort are called **ores**.

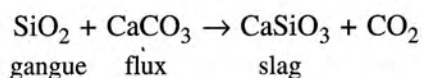
#### (v) Flux :

A flux is a substance that is added to the charge in a furnace to remove the gangue.

*Flux combines with the gangue to form a fusible mass called slag.*

#### (vi) Slag :

It is the fusible product formed when flux reacts with impurities (gangue) during the extraction of metals.

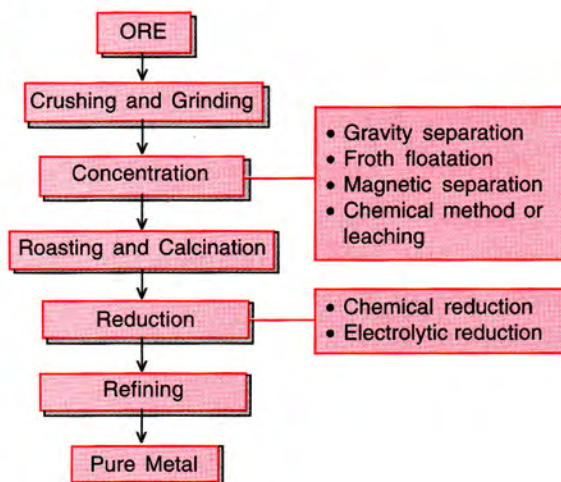


#### (vii) Smelting :

Smelting is the process of reducing the roasted oxide ore and removing the gangue with the help of an appropriate flux added with the ore. *It reduces the oxide ore to metals in the molten condition.*

### 7.10 STEPS INVOLVED IN EXTRACTION

Extraction of a metal from its ore consists of the following processes.





### 7.10.1 Crushing and Grinding

Ores are crushed into a fine powder in big jaw crushers and ball mills. This process is called **Pulverisation**.

### 7.10.2 Dressing (Concentration) of ores

The process of removing *gangue*, the rocky impurities like  $\text{SiO}_2$  present in an ore, is called *concentration of an ore* or **ore dressing** and the purified ore is called **concentrated ore**.

Concentration of the crushed ore is done mainly by the following methods.

#### (i) Hydrolytic (Gravity separation) method

**Principle :** The difference in the densities of the ore and the gangue is the main criterion.

**Method :** The ore is poured over a sloping, vibrating corrugated table with grooves and a jet of water is allowed to flow over it. The denser ore particles settle down in the grooves and lighter gangue particles are washed down by water (Fig. 7.3).

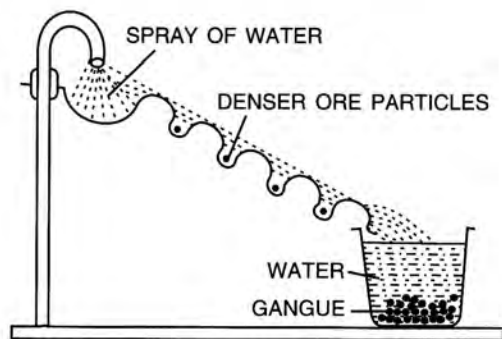


Fig. 7.3 Gravity separation using water and vibrating corrugated table

#### (ii) Magnetic Separation

**Principle :** Magnetic properties of the ores.

**Method :** The crushed ore is placed over a conveyer belt, which rotates around two metal wheels, one of which is magnetic. The magnetic particles are attracted to the magnetic wheel and fall separately apart from the non-magnetic particles (Fig. 7.4).

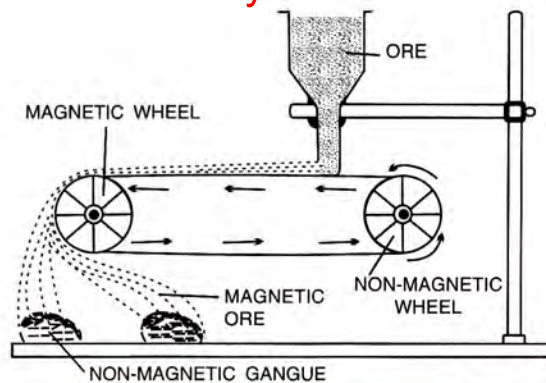


Fig. 7.4 Electromagnetic separation

#### (iii) Froth floatation

**Principle :** This process depends on the preferential wettability of the ore with oil (pine oil) and the gangue particles by water.

**Method :** The crushed ore is taken in a large tank containing oil and water and agitated with a current of compressed air. The ore is wetted by the oil and gets separated from the gangue in the form of froth (Fig. 7.5).

Since the ore is lighter, it comes on the surface with the froth and impurities are left behind.

Sulphide ores like zinc blende ( $\text{ZnS}$ ) Galena ( $\text{PbS}$ ) are lighter than their impurity. They are concentrated by froth floatation.

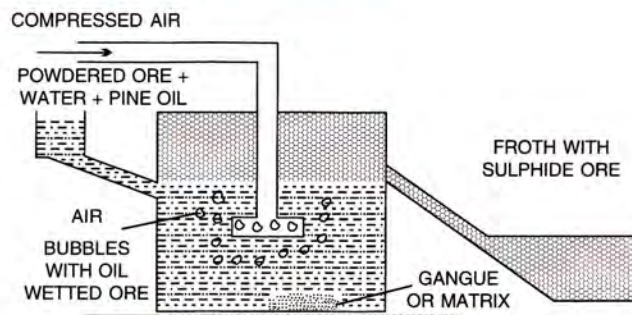


Fig. 7.5 Concentration of ore by froth floatation process

#### (iv) Chemical Method or Leaching

The ore is treated with a suitable reagent (acid, base or some other reagent) such that the ore is soluble in it but the impurities are not. The impurities are removed by filtration. The solution of the ore, *i.e.*, the filtrate is treated with a suitable



reagent which precipitates the ore (refer to extraction of aluminium).

### 7.10.3 Roasting and Calcination

**Roasting is a process of heating the concentrated ore to a high temperature in presence of air.**

Roasting is generally employed in case of sulphide ores or the ores containing metallic sulphides as impurities. It converts sulphide ores into oxides.

If an ore is a carbonate or a hydrated oxide, it is heated in the *absence of air* to a temperature that is high but insufficient to melt the ore. The process is known as **Calcination**.

#### Comparison of Roasting and Calcination

Roasting	Calcination
(i) The ore is heated in the excess of air.	(i) The ore is heated in the absence of air.
(ii) Generally, sulphide ores are roasted, so $\text{SO}_2$ is given off. $2\text{ZnS} + 3\text{O}_2 \xrightarrow{800^\circ\text{--}900^\circ\text{C}} 2\text{ZnO} + 2\text{SO}_2$	(ii) Carbonate and hydrated ores are calcined and $\text{CO}_2$ or water vapours are given off. $\text{ZnCO}_3 \rightarrow \text{ZnO} + \text{CO}_2$
(iii) Volatile impurities are removed as oxides ( $\text{SO}_2$ , $\text{P}_2\text{O}_5$ , $\text{As}_2\text{O}_3$ ) and the ore becomes porous and more reactive.	(iii) Moisture and organic impurities are removed and the ore becomes porous and more reactive.

### 7.10.4 Reduction of metal oxides

The roasted metal oxide is reduced by reducing agents like carbon, carbon monoxide or hydrogen. If the ore is not an oxide ore, it is first converted into an oxide ore by roasting or by calcination.

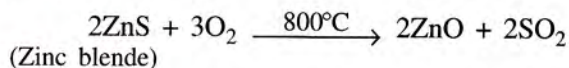
**Reduction can also be explained based on the activity series :**

Oxides of highly active metals like **potassium, sodium, calcium, magnesium and aluminium** have great affinity towards oxygen and so **cannot be reduced by carbon or carbon monoxide or hydrogen**.

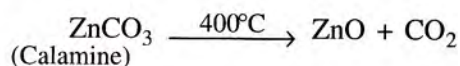
These metals are obtained by electrolytic reduction of fused metallic salts (halides or oxides) (Refer 6.9.3).

The **metals in the middle** of the activity series such as iron, zinc, lead, copper, *etc.*, are moderately reactive. These are usually present as sulphides or carbonates in nature.

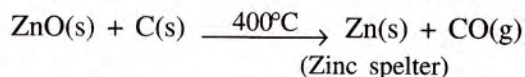
Sulphide ores are converted into oxides by heating in excess of air (**roasting**) as oxides are easy to reduce.



The carbonate ores are heated in a limited supply of air (**calcination**) to convert them into oxides.

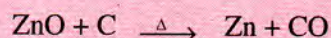


The metal oxides are then reduced by using suitable reducing agents (**carbon reduction process**).



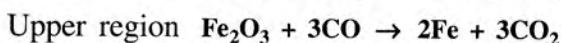
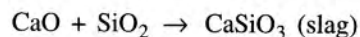
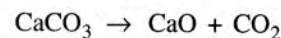
ZnO and Coke are heated in retort by producer gas ( $\text{CO} + \text{N}_2$ ) to get zinc spelter which on distillation or electrolytic refining gives pure zinc.

**Zinc oxide is not reduced by hydrogen or carbon monoxide. It is reduced only by heating with carbon.**



Similarly, the ore of **iron, i.e., haematite ( $\text{Fe}_2\text{O}_3$ )** is reduced in blast furnace by using **coke** and  $\text{CaCO}_3$  (flux).

Haematite, coke and lime stone are introduced from the top of the blast furnace and hot air is introduced at the lower region. Different reactions that takes place in blast furnace are :



**Observation :** Red metallic oxide gets reduced to greyish white metal.



Molten iron solidifies to give pig iron. It has limited applications, so is converted into steel after removing impurities and adding a calculated amount of alloy SPIEGEL (containing C, Mn and Fe).

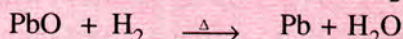
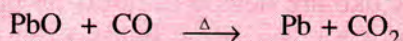
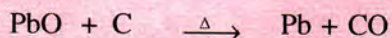
**Note :** The highly reactive metals can be used as reducing agents because they can displace metals of lower reactivity from their compounds. For example, in order to obtain manganese, its oxide is heated with aluminium powder.



These displacement reactions are highly exothermic. The amount of heat evolved produces metals in the molten state.

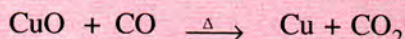
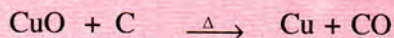
Lead and copper are obtained by the *reduction of their oxides with carbon*, carbon monoxide and hydrogen.

#### Lead oxide



**Observation :** Yellow lead monoxide gets reduced to greyish white metal.

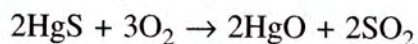
#### Copper oxide



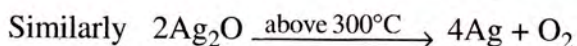
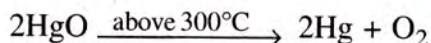
**Observation :** Black copper oxide is reduced to brown/red copper.

**Metals low in the activity series** are very less reactive. The oxides of these metals can be reduced to metals by heating alone.

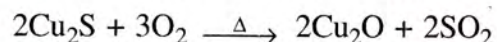
For example, firstly mercury sulphide (cinnabar), an ore of mercury, gets converted into its oxide by heating in air.



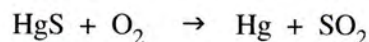
and finally, this mercury oxide, on further heating is reduced to mercury.



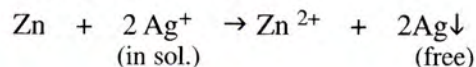
Copper which is found as  $\text{Cu}_2\text{S}$  in nature can be obtained from its ore by just heating in air.



Less active mercury is also obtained by merely heating its sulphide in air.



Silver and gold are obtained by displacement from solutions containing their ions by more electropositive metal zinc.



### 7.10.5 Refining of the metal

It is the separation of the above extracted metal from the residual impurity such as :

- (i) the presence of other metals and non-metals like silicon and phosphorus.
- (ii) unreduced oxides and sulphides of the metal.

**The method of purification used depends upon the**

- (i) nature of the metal,
- (ii) nature of the impurities present in the metal and
- (iii) purpose for which the metal is to be used.

#### (i) Distillation

Metals like mercury and zinc which are *volatile* distil over in pure form and the non-volatile impurity remains behind.

#### (ii) Liquation

Metals like lead and tin have *low melting points*, so they are heated on the sloping hearth of a furnace. The molten or fused metal flows away leaving behind the impurities (Fig. 7.6).

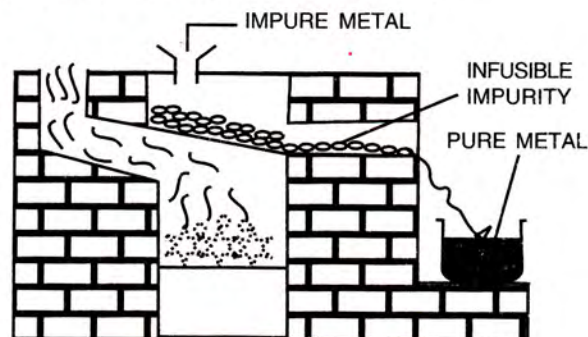


Fig. 7.6 Liquation process



**(iii) Oxidation**

Metals like iron which contain volatile impurities and can be easily oxidised are purified by this method. The volatile oxides of phosphorous, sulphur and other impurities rise to the surface and are removed while the molten metal is left behind.

**(iv) Electro-refining**

The impure metal is made the **anode**, while a thin sheet of pure metal is made the **cathode**.

Electrolyte used is a salt solution of a metal, which is to be refined. Pure metal deposits at the

cathode and impurities settle down forming anode mud.

Metals like **copper, aluminium** and **zinc** are refined by this process. (Fig. 7.7).

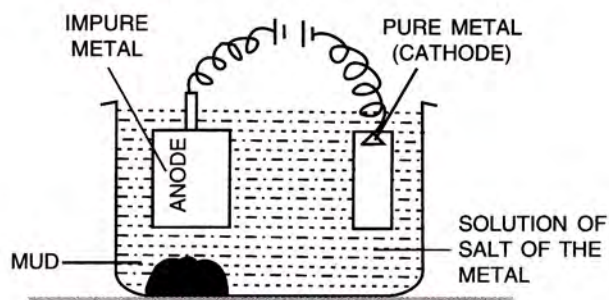


Fig. 7.7 Electro-refining

### EXERCISE-7C

1. Define the term 'metallurgy'. State the processes involved in metallurgy.
2. Which metal occurs as :
  - (a) a sulphide,                      (b) a halide,
  - (c) a carbonate,                      (d) an oxide.
 Also give the names of their respective ores.
3. Distinguish between :
  - (a) a mineral and an ore,
  - (b) an ore and a metallic compound.
4. Which metal can be extracted from each one of the following ores :
  - (a) bauxite    (b) calamine    (c) haematite.
5. State three objectives achieved during the roasting of ores.
6. Give the principles of :
  - (a) hydrolytic method,                      (b) froth floatation,
  - (c) electromagnetic separation.
7. Name :
  - (a) the processes involved in
    - (i) concentration                      (ii) refining of ores.
  - (b) two metallic oxides which cannot be reduced by carbon, carbon monoxide or hydrogen.
8. Explain the following terms :
  - (a) flux,                                      (b) gangue,
  - (c) slag,                                      (d) smelting.
9. Why does iron or zinc not occur free in nature ?
10. What do you observe when hydrogen is passed over heated copper oxide ?
11. Compare roasting and calcination.
12. (a) Name an ore of zinc.  
(b) Which process is applied to concentrate it ?  
(c) How is concentrated ore changed to oxide ?
13. Some metallic oxides can be reduced by hydrogen, carbon and carbon monoxide and some cannot. Explain.
14. How are the following metallic oxides reduced. Write equations :
  - (a) Iron (II) oxide,                      (b) Zinc oxide.
15. State why aluminium is extracted from its oxide by electrolysis while copper, lead, iron by reducing agents and mercury and silver by thermal decomposition.
16. An ore on being heated in air forms sulphurous anhydride. Write the process used for the concentration of this ore.
17. (a) On which factors does purification of metals depend ?  
(b) Name the methods used for purification.  
(c) How is electro-refining done ?
18. Complete and balance :
  - (a)  $\text{Ag}_2\text{O} \xrightarrow{\Delta}$                       (b)  $\text{MnO}_2 + \text{Al} \xrightarrow{\Delta}$
  - (c)  $\text{Cu}(\text{OH})_2 \xrightarrow{\Delta}$                       (d)  $\text{ZnCO}_3 \xrightarrow{\Delta}$
  - (e)  $\text{NaNO}_3 \xrightarrow{\Delta}$                       (f)  $\text{Pb}(\text{NO}_3)_2 \xrightarrow{\Delta}$
  - (g)  $\text{AgNO}_3 \xrightarrow{\Delta}$                       (h)  $\text{Cu}_2\text{O} + \text{Cu}_2\text{S} \xrightarrow{\Delta}$
  - (i)  $\text{HgS} + \text{O}_2 \xrightarrow{\Delta}$



## 7D. ALUMINIUM

## 7.11 COMMON ORES OF ALUMINIUM, IRON AND ZINC

Ore of Al	Chemical name	Formula
1. Bauxite	Hydrated aluminium oxide	$\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$
2. Cryolite	Sodium aluminium fluoride	$\text{Na}_3\text{AlF}_6$
3. Corundum	Anhydrous aluminium oxide	$\text{Al}_2\text{O}_3$

Ore of Fe	Chemical name	Formula
Red haematite	Anhydrous ferric oxide	$\text{Fe}_2\text{O}_3$
Brown haematite	Hydrated ferric oxide	$2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$
Magnetite	Triferric tetraoxide	$\text{Fe}_3\text{O}_4$
Iron pyrites	Iron disulphide	$\text{FeS}_2$
Siderite	Ferrous carbonate	$\text{FeCO}_3$

Ores of Zn	Chemical name	Formula
Zinc blende	Zinc sulphide	$\text{ZnS}$
Zincite	Zinc oxide	$\text{ZnO}$
Calamine	Zinc carbonate	$\text{ZnCO}_3$

## 7.12 ALUMINIUM

Symbol : Al	Relative atomic mass : 27
Colour : Silvery white metal	Atomic number : 13
Specific gravity : 2.2	Valency : 3
Electronic configuration : 2, 8, 3	
Position in Periodic Table : Period 3, Group IIIA (13)	

## 7.12.1 Discovery and Occurrence

Aluminium was discovered by *Oersted* in 1825. It is the most abundant metal in the earth crust. Aluminium is a reactive metal and so does not occur free in nature.

## 7.12.2 Extraction of Aluminium

*Hall and Heroult*, in 1885, developed the process for the extraction of aluminium.

Aluminium is extracted from its main ore **bauxite**  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ . Bauxite contains 60%  $\text{Al}_2\text{O}_3$ , the rest being sand, ferric oxide and titanium oxide.

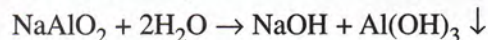
*Concentration of ore or purification of ore i.e. conversion of bauxite into alumina (Baeyer's process)*

Bauxite is grinded finely and heated to remove volatile impurities. It is then heated under pressure with conc. caustic soda solution for 2 to 8 hours at  $140^\circ\text{C}$  to  $150^\circ\text{C}$ .

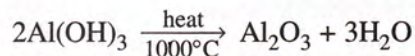


*Bauxite dissolves and forms sodium meta aluminate, leaving behind insoluble impurities called red mud.* Red mud consists of ferric oxide, sand, etc., which are removed by filtration.

On diluting sodium meta aluminate with water and cooling to  $50^\circ\text{C}$ , it gets hydrolysed to give aluminium hydroxide as a precipitate. The impurities dissolve in sodium hydroxide.



The precipitate is filtered, washed, dried and ignited at  $1000^\circ\text{C}$  to get alumina ( $\text{Al}_2\text{O}_3$ ).



The filtrate containing sodium hydroxide is again used to extract aluminium from bauxite.

Aluminium oxide due to its great affinity for oxygen is a very stable compound. It is not reduced easily by common reducing agents like carbon, carbon monoxide or hydrogen. Hence, *electrolytic reduction was chosen as the method for reducing alumina.*

*Difficulty faced in obtaining aluminium from alumina*

Electrolytic reduction can be done in molten state only. Alumina melts at approximately  $2050^\circ\text{C}$ . At this temperature, aluminium vaporises, so it was not easy to collect aluminium.

This difficulty was removed by Hall who found a suitable solvent in another ore of aluminium, *cryolite* ( $\text{Na}_3\text{AlF}_6$ ). When he applied the current to the molten mixture of alumina (20%), cryolite (60%) and calcium fluoride (20%), he saw some shining globules of aluminium appearing at the cathode. He got elated over the success of his



three years' concerted efforts and immediately ran excitedly to his professor and presented to him the few small pieces of the metal he had collected. It was February 23, 1886. Hall's discovery revolutionised the aluminium industry. *Aluminium which was once a costlier and rarer metal than gold became a cheap metal of common use in every home.*

### Electrolytic reduction of fused alumina (Hall-Heroult's process)

**Electrolytic cell :** Rectangular iron tank with sloping bottom. The sloping bottom of the tank facilitates the removal of the molten aluminium. The tank is lined with gas carbon.

**Electrolyte :** It is the mixture of molten alumina 20%, cryolite 60% and fluorspar 20%. Powdered coke is sprinkled over the surface of the electrolyte.

**Temperature :** The molten electrolyte is kept at 950°C by electrical heating.

**Voltage used :** 5 to 6 volts. A low voltage is used to avoid decomposition of the molten cryolite.

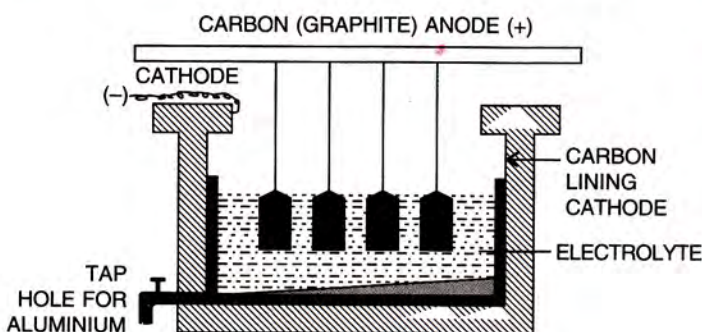
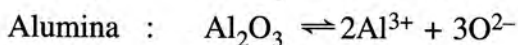
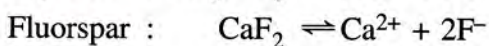
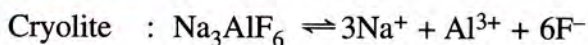


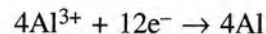
Fig. 7.8 Extraction of aluminium

### Reactions

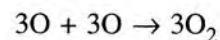
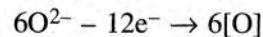


Positive ions formed in the solution are  $\text{Na}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Al}^{3+}$  while negative ions formed in the solution are  $\text{F}^-$ ,  $\text{O}^{2-}$ . Aluminium being lower in electrochemical series is preferentially discharged at the cathode while oxygen at the anode.

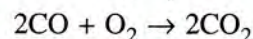
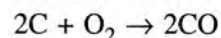
**Cathode :** (Inner carbon lining of the electrolytic cell)



**Anode :** Thick rods of graphite are suspended into the fused electrolyte.



Anode is oxidised to carbon monoxide, which further forms carbon dioxide.



*The anode has got to be replaced from time to time, as it gets oxidised by the oxygen evolved at the anode.*

When the supply of alumina decreases, the voltage suddenly jumps from 40 to 60 volts. If a bulb is attached to the apparatus, it will glow brightly. Then fresh alumina is added. Aluminium obtained is 99.8% pure.

Further purification can be done by electrolysis.

### Note :

1. **Cryolite :** Lowers the fusion temperature from 2050°C to 950°C and enhances conductivity.

2. **Fluorspar and cryolite**

- (i) act as a solvent for the electrolytic mixture.
- (ii) increases its conductivity since pure alumina is almost a non-conductor of electricity.

3. **Powdered coke** is sprinkled over the surface of the electrolytic mixture. It :

- (i) reduces heat loss by radiation.
- (ii) prevents the burning of anode.

### Refining of aluminium :

**(Hoope's electrolytic process).** The process uses an electrolytic cell which contains three layers of molten substance of differing specific gravity.

Molten impure aluminium forms the **bottom layer**. The bottom layer has carbon lining and serves as **anode**. Pure molten aluminium with carbon electrodes serves as **cathode** in the **top layer**.

The **middle layer** consists of a mixture of fluorides of sodium, barium and aluminium.



On passing current, aluminium from the middle layer passes to the top layer and an equivalent amount of it shifts from the lower layer to the middle one. Pure aluminium is tapped from the top. (Fig. 7.9)

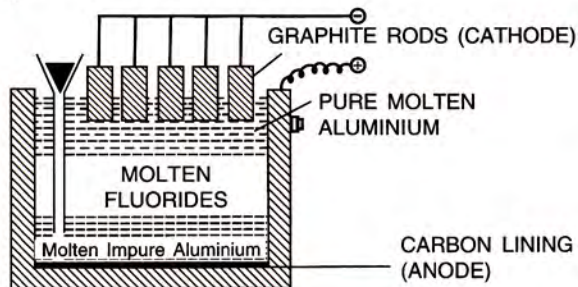
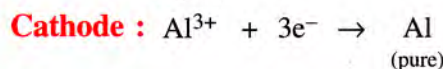
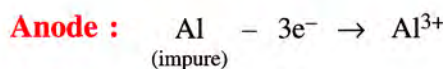
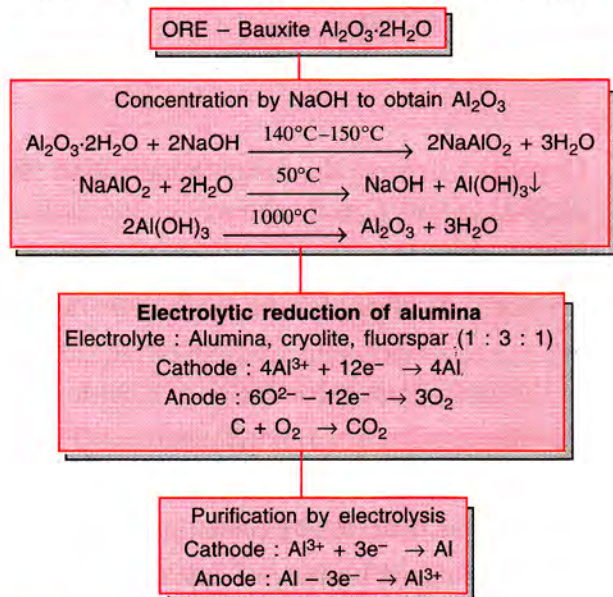


Fig. 7.9 Refining of aluminium



### Flow Chart for extraction of aluminium



## 7.12.3 Properties of aluminium

### (A) Physical properties

- (i) It is a silvery white metal.
- (ii) It is a light (*specific gravity* 2.2) but very strong metal, having high tensile strength.
- (iii) It is both malleable and ductile.
- (iv) It is a very good conductor of heat and electricity.

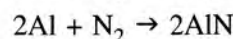
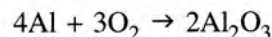
- (v) It can be highly polished to produce an attractive lustre.
- (vi) It has a m.p.  $660^\circ\text{C}$  and b.p.  $2050^\circ\text{C}$ .

### (B) Chemical properties

#### 1. Reaction with air

Its surface gets oxidised to oxide at room temperature which forms a thin but tough layer over the surface and protects the rest of the metal.

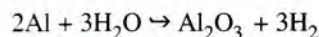
Aluminium powder burns in air at about  $800^\circ\text{C}$  forming its oxide and nitride with a bright light.



#### 2. Reaction with water

Water also has no action on aluminium due to the layer of oxide on it.

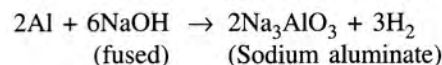
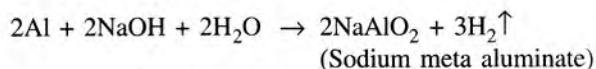
When steam is passed over pure heated aluminium, hydrogen is produced.



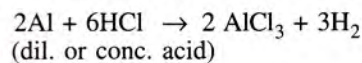
#### 3. Amphoteric nature

Aluminium reacts with bases (alkalies), as well as with acids.

It reacts with boiling caustic alkalies solution to produce meta aluminate while with fused alkali it produces aluminate.

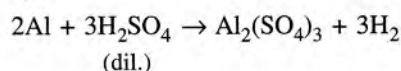


It reacts with acids to produce salt and hydrogen



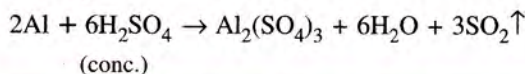
The reaction is slow in the beginning because the protective layer of aluminium oxide ( $\text{Al}_2\text{O}_3$ ) on the surface of aluminium resists the attack of acid. However, after some time, the oxide layer gets dissolved in HCl and the clean surface of aluminium reacts with HCl at an appreciable speed.

Dilute sulphuric acid reacts with the metal to liberate hydrogen.





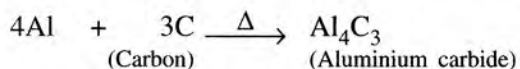
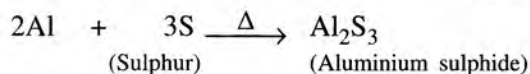
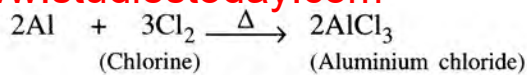
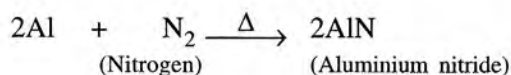
Concentrated sulphuric acid reacts with aluminium to produce sulphur dioxide.



Dilute or concentrated nitric acid does not attack the metal aluminium. It renders aluminium passive due to the formation of an oxide film on its surface.

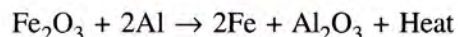
#### 4. Action on non-metals

Heated aluminium combines directly with non-metals :



#### 5. Reducing action

Aluminium is a powerful **reducing agent**. When a mixture of aluminium powder and iron oxide is ignited, the latter is reduced to metal. This process is called **aluminothermy**.



### EXERCISE-7D

1. State the position of aluminium in the Periodic Table.
2. (a) Give the chemical names and formulae of main ores of (i) aluminium (ii) iron (iii) zinc.  
(b) Which impurities are present in bauxite.  
(c) What is red mud, how is it removed ?
3. In order to obtain 1 tonne of aluminium, the following inputs are required. 4 tonnes of bauxite, 150 kg of sodium hydroxide and 600 kg of graphite. The aluminium compound in bauxite is aluminium oxide and the main impurity is iron (III) oxide. Aluminium is obtained by the electrolysis of aluminium oxide dissolved in cryolite.
  - (a) When bauxite is treated with sodium hydroxide solution, what happens to :
    - (i) the aluminium oxide,
    - (ii) the iron (III) oxide.
  - (b) (i) Name the process used for the purification of bauxite.  
(ii) Write the equation for the action of heat on aluminium hydroxide.
  - (c) (i) Write the formulae of cryolite.  
(ii) Write down the word which correctly completes the following sentence.  
By dissolving aluminium oxide in cryolite a ..... (conducting/non conducting) solution is produced.  
(iii) Why is so much graphite required for the electrolytic process ?  
(iv) Write the equation for the reaction which takes place at cathode.
4. Aluminium is extracted from its chief ore, bauxite. The ore is first purified and then the metal is extracted from it by electrolytic reduction.
  - (a) Write three balanced equations for the purification of bauxite.
  - (b) Name a chemical used for dissolving aluminium oxide. In which state of subdivision is the chemical used ?
  - (c) Write an equation for the reaction which takes place at the anode during the extraction of aluminium by the electrolytic process.
  - (d) Mention one reason for the use of aluminium in *thermite welding*.
5. (a) A to F below relate to the source and extraction of either zinc or aluminium :
 

A. Bauxite,	B. Coke,
C. Cryolite,	D. Froth floatation,
E. Sodium hydroxide solution,	
F. Zinc blende.	

  - (i) Write down the three letters each from the above list which are relevant to :
    1. Zinc,
    2. Aluminium.
  - (ii) Fill in the blanks using the most appropriate words from A to F.
    1. The ore from which aluminium is extracted must first be treated with ..... so that pure aluminium oxide can be obtained.



2. Pure aluminium oxide is dissolved in ..... to make a conducting solution.

(iii) Write the formula of cryolite.

6. Explain with reasons :

(a) In the electrolytic reduction of alumina, the graphite anode is gradually consumed.

or

Why the anode has to be replaced in this process ?

(b) Roasting is carried out on sulphide ores and not on carbonate ores.

(c) Carbon can reduce lead oxide but not aluminium oxide.

(d) Electrolytic reduction is done to obtain aluminium ?

(e) Why 'the food containing iron salts' should not be cooked in aluminium utensils ?

7. For each substance listed below, explain its significance in the extraction of aluminium :

(a) Bauxite, (b) Sodium hydroxide,

(c) Cryolite, (d) Graphite.

8. Distinguish between electrolytic methods of reduction and refining.

9. Give *three* ways in which the metal zinc differs from the non-metal carbon. At least one of the differences must be a chemical difference.

10. (a) Aluminium is a more active metal than iron, but suffers less corrosion. Why ?

(b) Explain and give reasons why aluminium vessels should not be cleaned with powders containing alkalis.

11. How does aluminium react with the following :

(a) Air, (b) Water,

(c) Acid, (d) Base.

## 7E. USES OF METALS AND ALLOYS

### 7.13 USES OF ALUMINIUM

(1) Being a **strong, light and corrosion resistant metal**, it is used in alloys.

(2) *Aluminium is light, it has high tensile strength, is resistant to corrosion, good conductor of heat, unaffected by organic acids and has attractive appearance. It is used as follows:*

(i) For making cooking utensils.

**Note :** When aluminium vessels like kettle are exposed to the atmospheric air, aluminium combines with the oxygen of the air and a film of aluminium oxide ( $\text{Al}_2\text{O}_3$ ) is formed at the surface of the kettle. This hard, tightly adhering film of aluminium oxide protects the kettle from the corrosive action of water.

(ii) In building and construction work.

(iii) Aluminium is highly malleable so it is used in the form of thin foils for packaging *i.e.* wrapping chocolates, medicines, etc, for capping milk bottles, in making tubes for tooth-paste, etc.

(iv) For painting electric and telegraphic poles, made of iron to prevent them from rusting.

(v) For making furniture and other household gadgets.

(3) *Aluminium has a strong affinity for oxygen. It is used :*

(i) as a deoxidizer in the manufacture of steel.

(ii) for making flash bulbs for photography.

(iii) for making certain explosives like *ammonal* (a mixture of aluminium powder and ammonium nitrate).

(4) Being an **excellent reflector of light**, aluminium is used *for making mirrors* for reflecting telescope.

(5) Aluminium being a *good conductor* of electricity, is used for the manufacture of cables for power transmission.

(6) As aluminium is **unaffected by sea water**, ships are made of alloys of aluminium.

(7) Aluminium is a good reducing agent so it is used in **aluminothermy**. *This process is used in joining (or welding) broken iron girders, rails and machine parts.*

(8) Aluminium amalgams liberate hydrogen when treated with water so it is used for carrying out reduction of organic compounds.



## GOLDSCHMIDT'S ALUMINOTHERMIC PROCESS (Thermite welding) :

In this process, **thermit** (a mixture of 3 parts of ferric oxide and one part of aluminium powder) is taken in a crucible with a hole at the bottom. The crucible is placed over the broken pieces of iron rails.

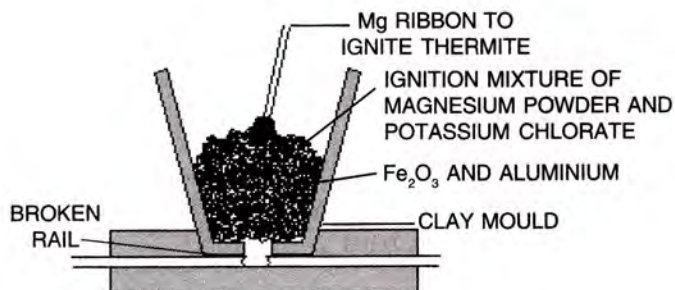
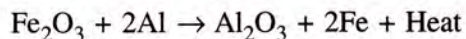


Fig. 7.10 Welding by aluminothermic process

An ignition mixture of potassium chlorate and magnesium powder is placed on the top of the thermit. To start the process, a fuse of burning magnesium is inserted into the ignition mixture which catches fire and ignites the thermit. A vigorous reaction occurs with the evolution of a large amount of heat. During this reaction, a temperature of 3000°C is achieved.



Iron formed from ferric oxide is allowed to drop over the gap between the broken pieces and they join together.

### 7.14 FORMS AND USES OF IRON

Depending upon the carbon content, various forms of iron are known such as :

- (a) **Cast iron** with carbon content 2.5–5%.

**Use :** It is used in drain pipes, gutter covers, weights and railings.

- (b) **Wrought iron** with carbon content 0.1 to 0.25%,

**Use :** It is used in chains, horse shoes and electromagnets.

- (c) **Steel** has high structural and tensile strength.

**Use :** It is used in the construction of buildings, overhead structures, machines, automobiles, instruments and in various alloys.

The properties of steel can be changed by heat treatment *i.e.* **tempering**.

When the steel is heated red hot at temperature above 800°C and immediately plunged into cold water or oil, *it becomes harder and more brittle*. This process is called **quenching** (hardening) of steel. **Specific machine parts are made by quenching.**

If this quenched steel is reheated carefully to a regulated temperature between 220°C – 300°C and then allowed to cool slowly, *it retains its hardness but its brittleness vanishes*. This process is known as **annealing** of steel. **Razor blades, springs, etc., are made by annealing.**

- (i) **Mild steel** contains a very low percentage of carbon (0.15 to 0.5%). Used to manufacture **nuts, bolts, etc.**
- (ii) **Hard steel** contains slightly higher carbon content (0.5-1.5%). It is used to make **tools**.

### 7.15 USES OF ZINC

Zinc has a strong electropositive character. It is used for the following purposes.

1. Zinc is mostly used for coating iron and steel sheets to prevent them from rusting. This process is known as *galvanisation*. Coating is done either by spraying molten zinc on the surface of iron or by immersing the iron object in a bath tub containing molten zinc. *Galvanised iron sheets are used for making pipes, buckets, dustbins, bath tubs, water tanks, wire and roofs.*
2. It is meant for making useful **alloys such as brass, bronze, German silver, etc.**
3. Due to strong electropositive nature, it easily forms Zn<sup>2+</sup> ions. It is used to make **dry cell** containers which act as negative electrode.
4. It is used for preparing lithographic plates for printing.
5. **Zinc dust** (zinc contains traces of ZnO) is used as a reducing agent for many organic reductions. These reductions are employed in the manufacture of **drugs, dyes, perfumes, etc.**



6. Zinc compounds are used for paints, electroplast (antiseptic), preservatives for leather and mordant for textiles. *Zinc carbonate is used for making cosmetics, especially face creams.*

## 7.16 ALLOYS

Alloy is a homogeneous mixture of two or more metals or of one or more metals with certain non-metallic elements.

The properties of alloys are often greatly different from those of the components. Gold is too soft to be used without a small percentage of copper. The corrosion and oxidation resistance of steel is markedly increased by incorporation of 15 to 18% of chromium and often a few per cent of nickel (stainless steel). The presence of carbon up to 1.5% profoundly affects the properties of steel. Similarly, a low percentage of molybdenum improves the toughness and wear resistance of steel. The hundreds of special alloys available are instances of the tailor-made nature of alloys to meet specific operating conditions. Amorphous alloys (used in transformer coils) are made by quick quenching of the molten metals.

An alloy melting in the range of about 51°C to 260°C, usually contains bismuth, lead, tin, etc. These alloys are called **fusible** alloys.

A steel containing up to 10% of elements such as chromium, molybdenum, nickel, etc., usually with a low percentage of carbon is known as **alloy steel**. *These added elements improve hardness, wear resistance, toughness and other properties.*

**Amalgam** : A mixture or an alloy of mercury with a number of metals or alloys such as sodium, zinc, gold and silver as well as with some non-metals is known as **amalgam**.

**Dental amalgam** is a mixture of mercury and a silver-tin alloy.

*Mercury does not form an amalgam with iron and hence mercury is commonly stored in iron bottles.*

## 7.16.1 Purpose of making alloys

Alloys are made to change the property of their major constituents to achieve a specific objective.

*For example :*

- (i) *Strength of iron is increased by making steel.*
- (ii) **Brass** is stronger than its components — copper and zinc.
- (iii) **Aluminium bronze** looks like gold.
- (iv) **Nichrome**, an alloy of Ni, Fe and Cr, is more resistant to electricity.
- (v) **Carboloy**, an alloy of tungsten, carbon and cobalt, is as hard as diamond.
- (vi) **Bell metal** is more sonorous than copper or tin.
- (vii) **Alnico**, an alloy containing aluminium, nickel and cobalt, can lift 60 times its own mass.
- (viii) **Solder**, an alloy of lead and tin, melts at 180°C. It is useful for making electrical connections because its melting point is lower than the individual melting points of both the component metals.
- (ix) **Type metal** (an alloy of lead, tin, and antimony) has a low melting point and can easily be cast. It is used for printing.
- (x) **Sodium amalgam** is much less reactive than sodium. *It is a liquid alloy at room temperature.*

The purpose of an alloy is to improve the specific usefulness of the primary component and not to adulterate or degrade it.

## 7.16.2 Reasons for alloying

Depending upon the purpose for which the particular alloy is used :

1. **To modify appearance and colour.**  
e.g. Aluminium bronze (Al + Cu) resembles gold as it is bright yellow.
2. **To modify chemical activity.**  
e.g. Sodium amalgam (Na + Hg) is less reactive than sodium.



## 3. To modify casting ability.

e.g. Type metal (Pb + Sn + Sb) expands on solidification and is easily cast.

## 4. To lower the melting point.

e.g. Solder (Pb + Sn) melts at 180°C which is lower than the melting point of lead or tin.

## 5. To increase hardness, and tensile strength.

e.g. Brass (Cu + Zn) is harder than copper. Duralumin has a strength up to six times greater than pure aluminium.

## 6. To increase resistance to electricity.

e.g. Nichrome (Ni + Fe + Cr) has more resistance (can produce much heat) to electricity than copper.

## 7.16.3 Method of making alloys

1. By fusing the metals together. *For example*, brass is made by melting zinc and copper.
2. By compressing finely divided metals. *For example*, **wood metal** : an alloy of lead, tin, bismuth and cadmium powder is a **fusible alloy**. This alloy is used in automatic sprinkler which provides a spray of water to prevent fires from spreading.

## 7.16.4 Alloys as solid solutions

Alloys can be considered solid solutions in which the metal with a high concentration is solvent and other metals are solute. *For example*, brass is a solid of zinc (solute) in copper (solvent).

Table 7.2 : Common alloys, their compositions, properties and uses

Principal metal	Alloy's name	Composition	Properties	Used for making
<b>Aluminium</b>	1. Duralumin	95% Al 4% Cu 0.5% Mg 0.5% Mn	1. Light but as strong as steel. 2. Hard and resistant to corrosion. 3. Highly ductile.	1. Bodies of aircraft, buses and tube trains. 2. Light tools. 3. Pressure cooker.
	2. Magnalium	90 - 95% Al 10 - 5% Mg	1. Resists corrosion. 2. Light. 3. Strong.	1. Aircraft 2. Scientific instruments. 3. Metal mirrors. 4. Light tools 5. Beams of balance. 6. Household appliances.
	3. Alnico	Al, Ni, Co, Fe	1. Light. 2. Shiny 3. Resists corrosion.	- Magnets
<b>Iron</b>	1. Stainless steel	73% Fe, 18% Cr, 8% Ni, 1% C	1. Resists corrosion 2. Lustrous, hard 3. Resistant to acids and alkalis	1. Utensils 2. Cutlery 3. Ornamental pieces 4. Surgical instruments
	2. Manganese steel	85% Fe, 1% C, 14% Mn	1. Durable, tough and hard	1. Safes. 2. Rock drills and 3. Armour plates
	3. Tungsten steel	84% Fe, 5% W, 1% C,	1. Very hard	1. Cutting tools for high speed lathes
	4. Nickel steel	95-98% Fe 5-3% Ni	1. Hard and elastic 2. Resistant to corrosion	1. Electric wire cables 2. Automobile parts
	5. Invar	Fe 63%, Ni 36% C 1%	1. Negligible expansion	1. Metre scales 2. Scientific instruments



<b>Zinc and Copper</b>	1. Brass	60 - 70% Cu 40 - 30% Zn	1. Malleable and ductile. 2. Can be easily cast. 3. Resists corrosion. 4. Yellow/Silvery in colour.	1. Decorative hardware, utensils. 2. Screws and handles. 3. Cartridge, containers. 4. Parts of watches. 5. Musical instruments. 6. Electrical goods.
	2. Bronze	80% Cu 18% Sn 2% Zn	1. Hard and easily cast. 2. Can take up polish. 3. Resists corrosion.	1. Medals. 2. Statues. 3. Utensils. 4. Bearing and 5. Coins.
	3. German silver	50% Cu, 30% Zn 20% Ni	1. White and light like Silver. 2. Malleable and ductile. 3. High electrical resistance.	1. Decorative articles. 2. Electric heaters, Rheostats. 3. Resistors.
	4. Bell metal	78%Cu 22% Sn	1. Sonorous (produces sound). 2. Hard and brittle.	1. Bell, gongs. 2. Statues.
	5. Gun metal	Cu 88%, Sn 8% Zn 1%, Pb 1%	1. Hard & brittle 2. Easily cut	1. Barrels of cannons. 2. Bearings, Gears, etc.
<b>Lead</b>	1. Solder or Fuse metal	Pb, Sn	1. Low m.p., high tensile strength	1. Welding 2. Fuse
	2. Type metal	75% Pb, 15% Sb, 10% Sn,	1. Low m.p. easily cast.	1. For printing blocks.

### EXERCISE-7E

- State a reason why zinc is used in :  
(a) galvanisation, (b) dry cells, (c) cosmetics ?
- State on what special properties the use of each of these metals depends :  
(a) aluminium, (b) zinc ?
- Explain the following :  
(a) Zinc is used to cover iron so as to prevent rusting of iron. Why ?  
(b) A neutral gas other than oxygen which is formed at the anode during electrolysis of fused alumina.  
(c) Nitric acid can be stored in aluminium containers.  
(d) In construction work, why is the alloy of aluminium-duralumin used rather than pure aluminium ?
- State the use of :  
(a) Cast Iron, (b) Wrought Iron,  
(c) Mild steel, (d) Hard steel.
- Which metal is used for :  
(a) making pipes, buckets, water tanks,  
(b) lithographic plates for printing,  
(c) making face creams.
- Give reasons, why aluminium is used in :  
(a) making alloys,  
(b) Wrapping chocolates,  
(c) Painting electric and telegraphic poles,  
(d) In aluminiothermy,  
(e) In making ships.
- Aluminium is used in thermite welding :  
(a) What is thermit ?  
(b) What is ignition mixture ?  
(c) Write reaction for process ?
- What is an alloy ? How do the properties of an alloy differ from its constituents ?



9. Calcium, copper, lead, aluminium, zinc, chromium, magnesium and iron.  
Choose the major metals from the list given above to make the following alloys :
- (a) Stainless steel, (b) Brass.
10. Both brass and bronze contain copper as major constituents. Name other elements in these alloys.
11. Name an alloy of :
- (a) aluminium used in aircraft construction.  
(b) lead used in electrical wiring or electrical work in joining metals.  
(c) copper in electrical appliances or household vessels.
- (d) zinc used in simple voltaic cells.
12. What is an amalgam ? State its use with an example.
13. (a) State two properties of brass that render it more useful for some purposes than its components.  
(b) a metal which forms a liquid alloy at ordinary temperature.
14. What is magnalium ? Name the main elements present in it ? Write its one use.
15. Name the constituents of :
- (a) Duralumin, (b) Solder,  
(c) Bronze, (d) Invar.

## SUMMARY

**1. Metals :** Mostly solids, (Hg is liquid) brilliant lustre, high density, good conductor of heat and electricity, malleable, ductile, tenacious.

They usually form basic oxides, are non-volatile and electrovalent chloride, have electropositive nature, react with dilute acids to liberate hydrogen (except Cu, Ag and Au), form positively charged ions which get deposited on the cathode on electrolysis of fused salts or their aqueous solutions. Some oxides like  $\text{Al}_2\text{O}_3$  and  $\text{PbO}$  are amphoteric.

**2. Non-Metals :** They usually form acidic oxides, are volatile and covalent chlorides, do not react with dilute acids to liberate hydrogen gas, usually form negative ions which get discharged at the anode, and have electronegative nature. Some oxides like CO, NO and  $\text{H}_2\text{O}$  are neutral.

**3. Metal Activity series :**  $\text{K} > \text{Na} > \text{Ca} > \text{Mg} > \text{Al} > \text{Zn} > \text{Fe} > \text{Pb} > \text{H} > \text{Cu} > \text{Hg} > \text{Ag} > \text{Pt} > \text{Au}$

- (i) Metals below hydrogen, cannot displace hydrogen from acids.  
(ii) Metals, which are higher in the series, can displace metals below it.  
(iii) The higher the position, the more active is the metal.  
(iv) Hydrogen has electropositive character and so placed among the metals.

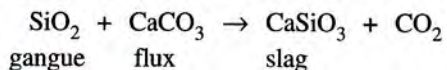
**4. Minerals :** Naturally occurring materials from which, metals can be extracted.

**5. Ores :** Minerals from which, the metals may be extracted economically in reasonably pure conditions.

**6. Flux :** A substance, added in the furnace during smelting to remove the gangue.

**7. Gangue :** Rocky and earthy impurities present in ores. Gangue may be acidic (like  $\text{SiO}_2$ ) or basic (like  $\text{FeO}$ ).

**8. Slag :** A substance formed when flux reacts with gangue.



**9. Roasting :** Heating the concentrated ore in the presence of air to remove volatile impurities like S, As, moisture, etc. and to render the ore porous.

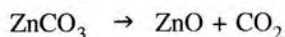
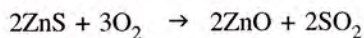
**10. Smelting :** The process of reducing roasted ore and removing the gangue.

**11. Methods of Concentration of Ores**

- (i) **Froth floatation :** Finely ground sulphide ores + water + pine oil + Air blast. Ore particles come up with the froth and float on surface. Rocky matter settles to the bottom e.g. zinc blende is concentrated by froth floatation.  
(ii) **Electromagnetic Separation :** Magnetic ores are separated by this process like iron ores.  
(iii) **Gravity Separation :** Heavier ores are separated.



**12. Roasting :** Concentrated ore heated in air without melting to drive off S, As, C and moisture. It makes the ore porous and even converts the sulphide and carbonate ores to respective oxides.



**13. Reduction of metallic oxides :** Less reactive metals like copper, zinc, lead and iron can be reduced by heating the metallic oxide by carbon, carbon monoxide or hydrogen. Reactive metals like K, Na, Ca, Mg and Al are reduced by electrolysis.

#### 14. Refining of metals

(i) **Distillation :** Easily volatile metals like Zn, Cd and Hg may be removed.

(ii) **Liquation :** Easily fusible metals like lead and tin may be removed.

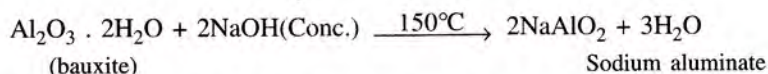
(iii) **Oxidation :** Easily oxidisable impurities like Cu and Sn may be removed by passing air blast through molten impure metals.

(iv) **Electrolytic refining :** Many metals like Cu, Al, Zn, Ag and Au may be refined using the impure metals as anodes, pure metal strip as cathode and metal salt solution as electrolyte.

#### 15. Extraction of Aluminium :

(a) **Purification of bauxite :** STEP 1 : Conversion of impure bauxite into sodium aluminate.

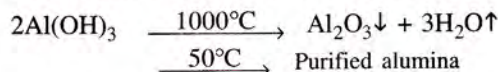
(Baeyer's process)



STEP 2 : Conversion of sodium aluminate into aluminium hydroxide.



STEP 3 : Conversion of aluminium hydroxide into pure alumina



(b) **Electrolytic reduction of purified bauxite (Hall-Heroult's Process) :**

*Electrolyte :* Purified alumina : Cryolite : Fluorspar (1 : 3 : 1)

*Electrodes :* Carbon lining as **cathode**; graphite rods as **anode**. Temperature : 950°C.

*Products formed :* Pure Al at the cathode; oxygen gas at the anode.

*Role of cryolite :*

(i) Melting point of alumina gets lowered from 2050°C to 950°C

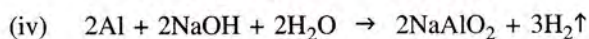
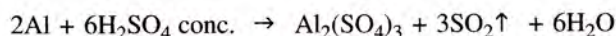
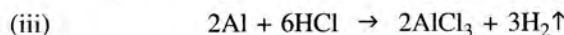
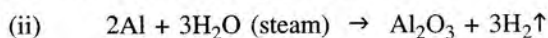
(ii) Increases electrical conductivity of the mixture.

(c) **Refining or purification (Hoopes electrolytic process) :** It is done in an electrolytic cell which consists of three layers of molten substances differing in specific gravity. Molten impure aluminium forms the bottom layer and acts as anode, pure molten aluminium forms the upper layer and acts as cathode. The middle layer is of fluorides.

at Anode :  $\text{Al} - 3\text{e}^- \rightarrow \text{Al}^{3+}$

at Cathode :  $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$

**Reactions of Aluminium :** (i) With moist air,  $\text{Al}_2\text{O}_3$  is formed. When ignited both  $\text{Al}_2\text{O}_3$  and AlN are formed.



sodium meta-aluminate

**16. Alloy :** Alloy is a homogeneous mixture of two or more metals; or of one or more metals with certain non-metallic elements.

**17. Galvanisation :** It is the process of giving a thin, adherent coating of Zn on iron sheets or wares to protect iron from rusting.



## MISCELLANEOUS EXERCISE

1. Name the following :
  - (a) A metal which is liquid at room temperature.
  - (b) The process of heating an ore to a high temperature in the presence of air.
  - (c) The compound formed by the reaction between calcium oxide and silica.
  - (d) A compound which is added to lower the fusion temperature of the electrolytic bath in the extraction of aluminium.
  - (e) Name an allotrope of a non-metal that allows electricity to pass through it.
  
2. From the list of characteristics given below, select the five which are relevant to non-metals and their compounds :
 

A. Ductile,	B. Conduct electricity,
C. Brittle,	D. Acidic oxides,
E. Basic oxides,	F. Discharged at anode,
G. Discharged at cathode,	H. Ionic chlorides,
I. Covalent chlorides,	
J. Reaction with dilute sulphuric acid yields hydrogen,	
K. 1, 2 or 3 valence electrons,	
L. 5, 6, 7 valence electrons.	

(Write the five letters corresponding to the correct characteristics).

3. The following is an extract from 'Metals in the Service of Man, Alexander and Street/Pelican 1976' :
 

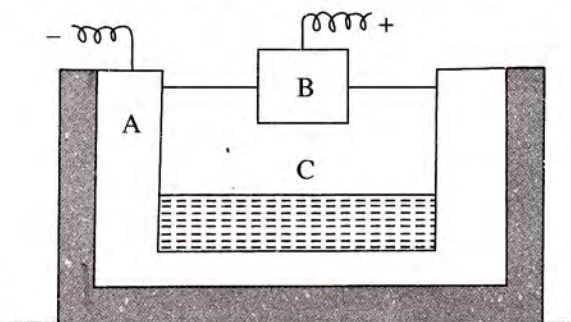
'Alumina (aluminium oxide) has a very high melting point of over 2000°C so that it cannot readily be liquefied. However, conversion of alumina to aluminium and oxygen, by electrolysis, can occur when it is dissolved in some other substance.'

  - (a) Which solution is used to react with bauxite as a first step in obtaining pure aluminium oxide ?
  - (b) The aluminium oxide for the electrolytic extraction of aluminium is obtained by heating aluminium hydroxide. Write the equation for this reaction.
  - (c) Name the element which serves both as the anode and the cathode in the extraction of aluminium.
  - (d) Write the equation for the reaction that occurs at the cathode during the extraction of aluminium by electrolysis.
  - (e) Give the equation for the reaction which occurs at the anode when aluminium is purified by electrolysis.

2008

- (a) The following is a sketch of an electrolytic cell used in the extraction of aluminium :
  - (i) What is the substance of which the electrodes A and B are made ?
  - (ii) At which electrode (A or B) is the aluminium formed ?
  - (iii) What are the two aluminium compounds in the electrolyte C ?
  - (v) Why is it necessary for electrode B to be continuously replaced ?
- (b) Brass is an alloy of :
 

A. Copper and tin,	B. Copper and zinc,
C. Zinc and lead,	D. Lead and tin.



2009

- (a) The metal oxide which can react with acid as well as alkali is :
 

(i) Silver oxide	(ii) Copper(II) oxide
(iii) Aluminium oxide	(iv) Calcium oxide
- (b) State the property of the metal being utilized in the following :

Use of metal	Property
Zinc in Galvanization	
Aluminium in Thermite welding	

2010

- (a) Which one of the following is **not** true of metals :
  - (i) Metals are good conductors of electricity
  - (ii) Metals are malleable and ductile
  - (iii) Metals form non-polar covalent compounds
  - (iv) Metal will have 1 or 2 or 3 electrons in their valence shell.



(b) Name the **main** constituent metal in the following alloys :

- (i) Duralumin                      (ii) Brass  
(iii) Stainless steel

**2011**

(a) Answer the following questions :

- (i) Name a metal which is found abundantly in the earth's crust.  
(ii) What is the difference between calcination and roasting ?  
(iii) Name the process used for the enrichment of sulphide ore.  
(iv) Write the chemical formulae of one main ore of iron and aluminium.  
(v) Write the constituents of electrolyte for the extraction of aluminium

**2012**

(a) Name the following metals :

- (i) A metal present in cryolite other than sodium.  
(ii) A metal which is unaffected by dilute or concentrated acids.  
(iii) A metal present in period 3, group 1 of the periodic table.

(b) The following questions are relevant to the extraction of Aluminium :

- (i) State the reason for addition of caustic alkali to bauxite ore during purification of bauxite.  
(ii) Give a balanced chemical equation for the above reaction.  
(iii) Along with cryolite and alumina, another substance is added to the electrolyte mixture. Name the substance and give one reason for the addition.

**2013**

(a)

	X	Y
Normal electronic Configuration	2, 8, 7	2, 8, 2
Nature of oxide	Dissolves in water and turns blue litmus red	Very low solubility in water. Dissolves in hydrochloric acid
Tendency for oxidising and reducing reactions	Tends to oxidise elements and compounds	Tends to act as a reducing agent
Electrical and Thermal conductivity	Very poor electrical conductor Poor thermal conductivity	Good Electrical conductor Good thermal conductor
Tendency to form alloys and amalgams	No tendency to form alloys	Forms alloys

Using the information above, complete the following:

- (i) ..... is the metallic element.  
(ii) Metal atoms tend to have a maximum of ..... electrons in the outermost energy level.  
(iii) Non-metallic elements tend to form ..... oxides while metals tend to form ..... oxides.  
(iv) Non-metallic elements tend to be ..... conductors of heat and electricity.  
(v) Metals tend to ..... electrons and act as ..... agents in their reactions with elements and compounds.

**2014**

(a) The main ore used for the extraction of iron is:

- (i) Haematite                      (ii) Calamine  
(iii) Bauxite                        (iv) Cryolite

(b) Heating an ore in a limited supply of air or in the absence of air at a temperature just below its melting point is known as :

- (i) Smelting                              (ii) Ore dressing  
(iii) Calcination                        (iv) Bessemerisation

(c) State the main components of the following alloys.

- (i) Brass                                      (ii) Duralumin  
(iii) Bronze

(d) Name the following :

- (i) The property possessed by metals by which they can be beaten into sheets.  
(ii) A compound added to lower the fusion temperature of electrolytic bath in the extraction of aluminium.  
(iii) The ore of zinc containing its sulphide.